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The Island indicates the site of the junction of the two tunnel sections.

THE FLOODING OF THE SPREE TUNNEL AT BERLIN.—[See page 279.]

Fundamentals—II*

The Essential Principles of Engineering Practise

By Onward Bates, M. W. S. E.

Concluded from Supplement No. 1895, page 267.

Let us now pass on to the object of the engineer in learning to direct the forces of nature. The definition states it to be "for the use and convenience of man," and we are led to inquire what manner of use and convenience is intended. Is it to make man more comfortable, to feed and clothe him better than before, to add to his life new and greater opportunities of education and pleasure, and in general, to advance the state of civilization which surrounds him? Yes, all of these, and still more: Man is not simply an animal with his desires limited to a full stomach, an agreeable temperature of the body, and pleasing sensations of the mind. Man is a creature with a soul, that something which we do not fully understand and cannot describe, and which, for want of a better comparison, we may liken to the electric energy which pervades the world. We are all endowed by nature with moral as well as with mental and physical attributes, and that which is best in us is to be discovered and conserved and developed. To do this we must begin with the right fundamentals and deal with our fellow men on a higher plane than of natural and human laws. Let us engineers yoke the forces of nature and make the world richer and more comfortable and pleasant to live in and let us not forget to practice and to instill into the lives of others the moral relations which should exist among men, and which yield greater returns that the mere catering to the desires of body and mind. Let him who believes the object of engineering is limited to the production of beneficial physical conditions which may profit men if they choose to avail themselves of those conditions, consider the length and breadth and depth of Telford's statement; and if he is not devoid of reason he will get some idea of the responsibility and dignity of his relationship to other men.

The engineer is accepted among men as an arbiter between them, acting under the laws of nature and the laws of man. He must respect the laws of the commonwealth, and in addition, he is, in cases where the common law is insufficient to secure right ends, selected and deputized to make decisions according to the laws of equity and justice.

In every agreement for the performance of engineering work the engineer is charged with the duty of deciding disputed questions between the parties to the contract. It is common to specify that his decision shall be final and binding upon both parties. He is the judge of quality and of quantity and of all the covenants between the parties. Indeed, some contracts give the engineer such authority that if literally construed, would enable him to deprive one of the parties of life, liberty and the pursuit of happiness guaranteed by our national constitution. Such extreme cases of delegated power are, however, to be taken as attempts at over-reaching by the party drawing the contract, and though it may be agreed upon between the parties that no appeal shall be taken from the decision of the engineer, such an agreement must fail as subversive to the natural rights of men, and contrary to the law of the land.

In line with the powers given to the engineer in the performance of contract work, he is becoming more in demand as an arbitrator in cases of dispute between the parties to a contract. The fact that the covenants entered into for engineering works involve technical questions of quality and of quantity and of processes, of feasibility and of capacity, makes it difficult and almost impossible for some disputes to be settled by the ordinary appeal to courts of law, and arbitrators are selected to render decisions in accordance with justice and equity. In arbitration cases, where the engineer is the sole arbitrator under the contract, and in other cases where he is chosen to act as an arbitrator to decide on the principles of equity and justice, he works under higher laws than the decrees and ordinances of local and national authorities, and he cannot be too much impressed with the authority vested in him to judge between his fellow men. With such responsibility laid on his mind he must think in larger terms than are contained in mathematical text books and in the rules for performing work. He becomes a judge of men and is required to make allowance for their weaknesses. He must give to each side his due, according to reason and the law of God to man, and he must be fair and impartial in deciding conflicting claims. These are fundamentals of equity and are binding on one who is appointed to decide in accordance with equity. He must recognize that exact calculations may be misleading because of uncertainty in the data on which they are based. He must also get the truth from his witnesses, remembering that a witness may be led into telling a technical falsehood when he is endeavoring to tell the whole truth and nothing but the truth, and this is especially apt to be the case when under examination by a shrewd lawyer whose object is not to elicit the truth, but to make the evidence point to some predetermined conclusion. In such cases the arbitrator has only himself to lean upon and cannot escape making his own decision when dealing with questions which are clouded with lengthy testimony and so involved that their only solution is in beginning with fundamental facts and principles and working upward from them to determine what of the testimony is relevant and material.

As nothing can exist without a foundation, so there are always fundamentals to be considered in deciding any questions. Some things are fundamentally right and others are fundamentally wrong. A knowledge and observance of fundamentals leads to correct conclusions. A neglect of fundamentals leaves the engineer up in the air, without a foundation to support him. Logical reasoning brings one into acquaintance with fundamentals. Mathematical computations, accurate workmanship and strict observance of rules of procedure only lead one astray if they are not founded on right fundamentals. Starting right and keeping the right in view one does not make mistakes, although his capacity may limit the amount of his accomplishment. With right fundamentals this amount is determined by his equipment of professional knowledge and skill. Do not understand that I decry professional knowledge, without which the highest rounds of the professional ladder cannot be reached. Nevertheless, professional attainments are but as chaff in the wind if they are not applied with due regard to fundamentals which reason and common sense make known to us.

My address thus far is written from the view-point of one who may be said to be looking backward over his experience and is now considering the application of fundamentals to a practice in which large questions are considered and the factors entering into these questions are supplied by others.

Young men who listen to me may say in their minds, "What has this to do with me? I am only an assistant; I work under orders, doing what I am told to do. I make calculations and plans and do instrumental work as directed by others." This is all very well; you are engaged as you ought to be, and my advice to study and utilize fundamentals is of more importance to you than to older men who have not so much ahead of them. You cannot get away from the necessity of being fundamentally right, nor can you shift the responsibility for being so to your employers. You only have a better opportunity of preparing for future success by applying fundamentals to your present work. The principle applies to details fully as well as to aggregates, and the habit acquired of doing each thing because there is a fundamental reason for it is the best preparation for judging the work of other men which you will be called to do in coming years.

It is the early years of an engineer's practice that determine his usefulness in later years. It is not only necessary for you, while working under instruction, to prepare the foundation for the successful conduct of affairs when you come into control of your own time and must direct the energy of others, but as different foundations are required for different structures, it is imperative that you should choose those fundamentals which will serve as a foundation for the kind of man you wish to make of yourself. Right here is perhaps the turning point in the career of many a man. Choose to be the right kind, form your ideal, and work to it as if it were a plan traced on drawing paper. Do not think all that is required of you is to hew to the line and that there are no materials for the engineer to work with except those enumerated and whose qualities are set forth in engineering text books. Do not let your ideal fall short of the highest type of manhood—that kind which makes an impression on fellow men and helps them to higher manhood. Study human nature, remembering that your dealings with men are more important than your use of inanimate materials and that as your practice as an engineer advances you will be called to weigh and to value men, and to be morally responsible for their successes as well as for your own. Perfect yourselves in technical training in the specialty which engages your services, but do not give up your life to it. Take a broad view of the work of other specialists because as an independent engineer—which you must hope some day to become—you will have to judge of their work and incorporate it with your own. It is an acknowledged fact that a complete knowledge of one specialty is an education for judging other specialties. The competent specialist finds remunerative employment at times when others seek it in vain, and this fitness for doing particular things should be acquired while young, as a sort of professional insurance. When you have secured this insurance, learn all you can of other specialties, because, with increase in rank, you will have to include them in your practice. You will then have use for the acoustical engineer and the illuminating engineer, and for sundry other kinds of engineers. Such men are most useful and they will probably discard the restrictive titles they have adopted when they in turn reach the stage of employing specialists in other lines. In the meantime, it is a pity that they are unwilling to be called, civil, or mechanical, or electrical, or mining engineers. Only yesterday a young man told me he was going to be an engineer. He said he was specializing in electricity in a technical school, the name of which I do not mention. I did not learn just what limited education he aspired to and I guessed he was qualifying himself for a lineman—a commendable occupation, which should give him a good living—and that he will probably blossom out with a card designating himself as a "wire-pulling engineer." That will be altogether proper under a system permitting the assumption of titles at will.

Among the engineers composing this society and whose title is guaranteed by their membership certificate there are specialists in all lines covered by our profession, many of them having attained eminence in particular directions. Still, it is scarcely possible that any of our members are personally qualified in all branches of the profession, and while giving the best of service in our own specialties, we should never fail to protect our clients by securing the assistance of competent specialties in work we control which is of a character different from that to which we have given our own attention. This is co-operation. We constantly speak of our pride in the profession and of our desire to elevate it and to build up a proper spirit among its members, and there is no way to accomplish this end which is better and more proper than to employ our fellow engineers and to combine their best work with our own. An engineer cannot be all things to all men, and he attains his greatest value as he adds to his own strength the strength of others.

The highest position to which an engineer may be elevated is to be in charge of interests and operations of such magnitude that his detail work must all be done by his assistants, including specialists of different kinds. In this position his duty is to choose, for the different classes of work, assistants who are qualified for the duties he requires of them, to see that their work is properly done and to generally exercise such supervision as will result in efficiency. He then becomes a real "efficiency engineer," and may have in his staff "efficiency specialists," who will count and value the movements of the legs and arms of the workmen who do the real work.

There was never a time when so much was expected of engineers as at present. The profession has never before received the recognition it now enjoys. Never before have there been so many and such great enterprises in which controlling positions must be given to engineers, for the reason that the success of these enterprises depends on applying the forces of nature for the use of man. There are engineers capable of filling these places who are recognized and are appointed to them. The qualification for such a place is a special knowledge and experience in line with the enterprise, and what is not less important, a knowledge of fundamental principles which will enable the engineer to correctly solve questions involving the application of natural laws and the use of and right relations between men.

If there be any merit in this discourse, I dedicate it to our young members. Young men need foundations, old men need roofs. Young men must build upward old men whose capital is experience, may follow the example of the architects of modern buildings, who seem to have their fundamentals at the top, and to build downward, suspending their columns from the interior frame which the engineers have provided. The young engineer who appreciates that he must be the architect of his own fortune may make a great and noble structure of it if he builds on the right fundamentals.

Examples are more effective than demonstrations

* Paper read before the Western Society of Engineers, and published in its Journal.

with words and it is healthful and helpful to study the life and work of such engineers as excite our respect and admiration. All men have faults, but if we look for the good in them, we find inspiration and instruction to aid us in striving for the ideal we have adopted, and if we study enough examples we may construct a composite ideal combining the admirable qualities we have observed in many men, and if in addition we have selected our examples from among those who have passed from us into another world, we have no occasion even to remember such faults as they may have possessed. Study our list of members and you find scores of names among the living and dead, whose personal qualities and professional attainments ennoble the profession. It is not fitting in this connection to mention names of living members and I hesitate to select names from among our honored dead, lest in my imperfect knowledge of their virtues I may not arrange them in their order of merit, but as I write this there comes to me the memory of Pope, Parkhurst, Dun, Lassig and many others to whom I have been indebted for their influence and example. I call to your attention another example by quoting from recent Chicago newspapers. A telegram from Gary, Ind., reads:

"When Harry N. Atwood passed over the sand dunes near Miller, Ind., he gave the natives a view of modern aviation. They were well acquainted with antiquated aviation, for Octave Chanute, the father of aviation, made his first flights in that locality in 1896. Work in the steel mills was practically suspended in Gary and scores of locomotives and the steel company's whistles heralded the approach and passing of the aviator."

Another newspaper in an editorial, referring to the great aviation meet in Chicago in August of this year, states:

"There probably will not be a contestant in the events who will not turn his thoughts back to the days only a few years in the past when Octave Chanute, a Chicago engineer, was conducting aeroplane experiments on the shore of Lake Michigan, only a few miles from Grant Park. Every man who guides a machine in its flight will be willing to acknowledge that to Chanute more than to any other man belongs the credit of making flying possible.

"The debt to the Chicago experimenter has been acknowledged by most successful aviators. In every machine which will start upward from Grant Park at the aviation meet there doubtless can be found substantial evidence of the constructive genius of Octave Chanute. He lived long enough to see the practical application of principles which he had formulated.

"Fifteen years ago aeroplanes were tested in the sand dunes region of Northern Indiana. The experimenters had the wings and the tail of the bird-like machines, but could apply no motive power excepting that which a fair running start down a hill could generate. The 'landing' invariably was a wet one, for the end of the journey was the lake. There probably would be no meeting of aviators one week from Saturday if Octave Chanute and a few other men had not been willing to face ridicule in the effort to learn the secret of the mastery of the air."

Octave Chanute was one of the best friends this society ever had, and likewise a friend and encourager to each of our members who enjoyed his personal acquaintance. He was a persistent seeker of fundamentals and I advise all who have not done so to read his memoir, published by this society, and to profit by his example. Indeed, I think a condition should be attached to the award of the Chanute prizes—that the recipient should read this memoir.

We hear much in these days about a broader education for engineers. The subject is frequently mentioned among those who, in the course of their practise, have learned the necessity for breadth of vision and action, and I think practicing engineers will generally agree with me that this lack of breadth is a real weakness in our present make-up. The universities are considering the subject with a view to providing a remedy for this weakness, but the professors and graduates sometimes make the mistake of assuming that engineers are made at the universities. The education of an engineer is neither begun nor ended in the schools; the university cannot make an engineer; it cannot even give him an engineering education. It can only partially equip him for his journey through life. He must find his own way across the rivers and over the mountains, learning how to overcome the dangers which confront him; to make use of the favorable features of topography, and to find pleasant camping places as he travels. The engineer's education is never completed. This would mean that he knows and obeys all of the laws of Nature and man, which is reducing the proposition to an absurdity. The very fact that he must be a learner all through his life is the chief charm of his occupation. What he accomplishes on his journey and where he finally ends must depend on himself. He will be a successful engineer if he leaves a record of useful work and if his own life and the lives of others which come in contact with his own are made happier and better.

He must be a man among men of all occupations, making himself a useful citizen and an agreeable member of the society in his community, increasing his opportunities for helping others and by making his own self and attainments known to them, enlarging his circle of professional clients. He should recognize his obligation to the commonwealth and should respond to its calls for duty. Such calls for advice and assistance frequently go begging without response, losing at the same time chances for securing recognition of the profession. Because engineers build railways and power plants and other utilities, there is no reason why they should not take their places as good citizens, interested in and assisting in every good work intended to better the conditions of their race.

All of this he will accomplish if he strives for the right ideal and builds on the proper fundamentals.

A Flying Laboratory

The Observatory on Board the Schwaben

THAT practical genius of the Germans which causes the prompt transmutation of newly discovered scientific truths into terms of concrete utility has just received a fresh exemplification at the instance of Director Colsman of the Zeppelin construction and transportation companies.

Under his orders the magnificent new airship "Schwaben" has had partitioned off from one end of the passenger-cabin a small room elaborately fitted with appliances for the making of scientific and technical experiments while *en route*, in other words a "midair laboratory."

The improved manner in which dirigibles are now operated insures flight as a rule over a definite course and at a fairly constant altitude. Such comparative uniformity of conditions permits the keeping of an aerial log, and the determination of various problems in regard to the various factors, internal and external, which affect flight. The midair laboratory offers advantages for the study and solution of such problems, obviously superior in many important respects to the facilities provided on *terra firma* either in workshop or in the university, since the investigator is in a position constantly to "check" his preconceived theories by the observation of actual facts.

The passenger-cabin on the Zeppelins is built upon an enlargement of the gangway running between the rear and forward gondolas. On the "Schwaben" the laboratory is a small but comfortable room communicating with the cabin by a door and containing a single one of the seven windows visible from the outside. The floor-space is about 100 square feet, and a photograph of the interior shows not only scientific instruments, but a comfortable easy chair, and the tap of a water-tank with a porcelain sink beneath.

Remarkable success of construction has been attained, as proven by the fact that the familiar disadvantages of dirigible travel, the noise of motors and propellers, the strong draught, and the vibration, have been almost entirely eliminated. Moderately sensitive instruments, such as galvanometers and electrometers can be used without precautions, and telephone sounds can be heard plainly without covering the free ear, while mere whispers can be detected with the free ear closed.

It is to be expected that this laboratory will throw light on a great variety of questions, meteorological and otherwise, such as the effects of sunlight, of warmth and humidity, the variations of wind-pressure, and direction of air currents, but its chief aim at present is the investigation of atmospheric electricity and wireless telegraphy, with special reference to the use of the latter as a means of directing the airship by night or in thick weather.

As respects the former, it is of special importance to learn how such a great airship is affected as it passes through the local magnetic field, and the inherent possibilities of receiving or giving off an electric charge. Prof. Dieckmann, an authority on these subjects, says, "Conditions in this connection are not so simple as has been hitherto supposed. Among other things a complication appears to arise from the fact that the exhaust gases of a gasoline motor leave the exhaust charged positively and the airship negatively. At the same time the exhaust gases effect an increased conductivity of the air."

The apparatus used in these experiments is very simple, consisting of an "equalizer" fixed to the body of the aircraft, and projecting on rods into the air above and below, these of course being carefully insulated. The "equalizer" consists merely of a plate of platinum covered with radium, and this little "equalizer" quickly takes the potential of the surrounding space. The differences of potential are then read by means of the electrometer. These differences are by no means small, for the "equalizer" underneath the ship often runs as high as 1,000 volts per meter.

The overhead differences run much smaller, so much so that there is practically no danger of a spark. By a similar simple device, the "storm-indicator," the observer is warned of abnormal electrical conditions in the neighborhood of the ship at any portion of its course.

The experiments with wireless telegraphy in the flying laboratory are even more interesting and important. They have two main objects, the sending of meteorological advices, or weather-warnings, and the elaboration of a definite system for indicating the direction of movement through the air, so that in rain, mist, fog, or starless nights the pilot may be able to find his bearings and keep to his course.

Such a system has already been worked out and was successfully employed in a flight made last August.

The principle is exceedingly simple, and may be stated as follows: The energy radiated from any wireless sending station calls forth a response at any given receiving station directly proportional in strength to the distance of the latter. The receiving of messages, however, is usually by the ear; consequently the distance is directly proportional to the loudness of the sound. The comparative loudness of the sound is measured by an ingenious little device called a distance meter. This consists merely of an ordinary instrument for measuring electrical resistance, connected in parallel with the telephone, and provided with a linear scale in which zero stands for the point at which sounds cease to be audible. The divisions of the scale indicate the intensity of sound at given distances. If now not less than three land-stations using the same wave-length send signals to the airship, one after the other at brief intervals of time, the spatiometer will show the distance of each station and likewise their relative distance. By consulting a chart it is very easy to calculate from these data the latitude and longitude of the ship, and likewise by repeated measurement both the speed and the course of the dirigible may be determined.

In this connection Prof. Dieckmann mentions an automatic arrangement for indicating direction of movement already in operation at Gräfelfing, near Munich. Each of four sending-stations, 1, 2, 3, and 4, located at the corners of a square, has a prescribed sending time. "Each station sends its place-signal every five minutes for a period of one minute's duration, so that a balloon or an airship receives them in rotation at intervals of about 15 seconds, and can determine the relative intensity of sound."

We shall await with interest future developments of this novel installation of a working laboratory in a swiftly moving airship.—*Abstracted from Prometheus.*

Social Equilibrium.—It is commonly understood that there is some natural law which governs the distribution of the wage earners in each country over the several professions and callings which are open to the individual. Fundamentally, of course, the law at work here is one of demand and supply, though its detailed mode of working is not very easy to realize, for, while it is obvious that an urgent demand will cause an appreciable rise in the remuneration offered in the particular field in question, slight fluctuations in demand would, at most, cause only slight increase in the payment offered, and it is not quite easy to see how the average individual becomes aware of such slight fluctuations, so as to take advantage of them. On the other hand, it may presumably be taken for granted that excessive fluctuations rarely or never occur, so that somehow or other the balance is maintained without allowing any critical conditions to arise. It is interesting, in this connection, to observe some actual figures relating to the distribution of the population among different occupations in the United States in the past, as set forth in the Statistical Abstract of the United States, published in 1909. The table which is given below shows the distribution in percentages of the male population over ten years of age, engaged in a number of specified occupations. An inspection of these figures will show that while certain changes have occurred which are not by any means negligible, yet the general balance has been essentially unchanged.

	1890. Per cent.	1900. Per cent.
Agricultural pursuits	41.6	39.6
Professional service	3.4	3.5
Domestic and personal service.	13.6	14.7
Trade and transportation......	16.4	18.0
Manufacturing and mechanical pursuits	24.7	24.3

Fig. 1.—Bronze Containing 10 per cent Tin, in the Strained Condition. Magnified About 85 Diameters.

Fig. 2.—The Same Specimen as Fig. 1, After Annealing. Note Large Regular Crystals. Magnified About 85 Diameters.

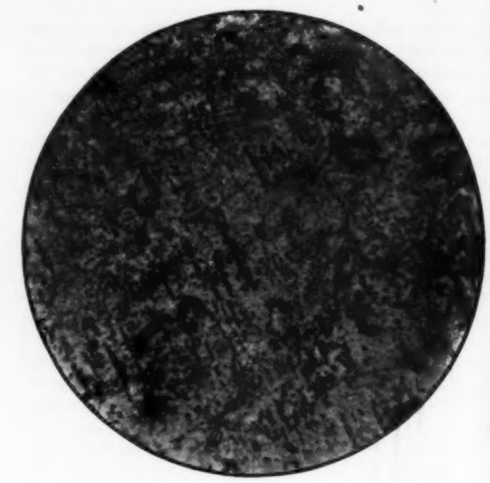

Fig. 3.—German Silver, Containing About 63 per cent Copper, 18 per cent Nickel, 19 per cent Zinc. Strained Specimen, Magnified 85 Diameters.

The Crystalline Constitution of Metals

The Influence of Annealing on Crystalline Structure

By Thomas A. Eastick

Within recent times the search for metals and alloys having the requisite properties to fit them for the varied and complex uses of modern engineering practice, has become very keen and has also helped to build up a new science, a science, too, which is unique in its practical utility. It is known as metallography.

It is quite a common thing among laymen, and even among some engineers, to regard metals and alloys as

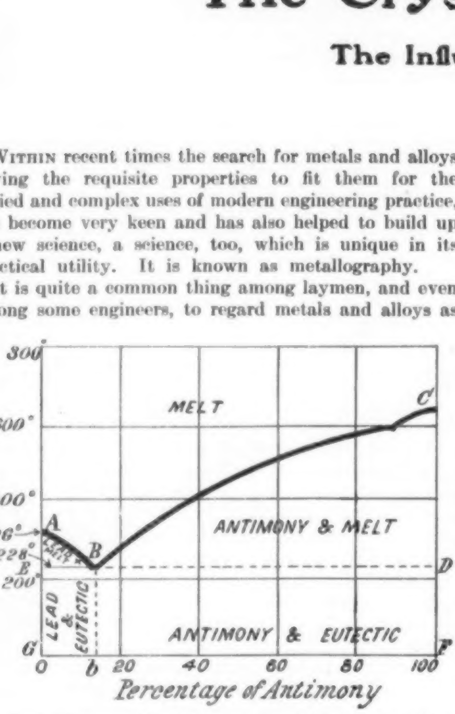

Diagram Showing Condition of Lead-Antimony Alloys at Different Temperatures.

being amorphous, homogeneous masses of matter having those distinctive metallic properties such as hardness, toughness, malleability, etc. That such is not the case, however, is now very well known to scientists. Practical metallurgists have, in fact, applied the principles of metallography and the microscopic examination of metals to practical purposes with extraordinary success.

One of the first notices that we have on the subject of the constitution of metals is to be found in the works of Robert Hooke, published in 1665; Hooke describes the crystallization of lead from its alloy with silver with remarkable clearness and accuracy.

Reaumur in 1722 used to examine the structure of iron and steel with the microscope regularly, and made some very sagacious remarks on the influence of thermal treatment on the form and size of the crystals.

H. C. Sorby of Sheffield, England, however, is regarded as the founder of metallography and he published between the years 1865 and 1885 numerous papers and micro-photographs, some of which were beautifully executed, on the constitution of iron and steel.

After Sorby came numerous workers; Martens published some excellent results from the Charlottenburg laboratories; Charpy Osmond and LeChatelier, in France, contributed greatly toward the advance of the science by devising new apparatus and methods of examination.

While the microscope and photography are the two chief servants to metallography, there are, of course, a great many other branches and considerable theory is used in connection with the micro-photographs to solve the numerous problems met with in the examination of metals.

When a metallic substance is under examination, the first determination that is made is the cooling curve. If we take an absolutely pure metal and melt it, and then allow it to cool and take the temperature, say, every minute, and then plot the results, we obtain a curve similar to *a* in the chart. It will be noticed that there is a very perceptible break in the curve about half way down. This break is due to the metal solidifying, as when we melt or freeze water the temperature remains stationary until all the water is either frozen or melted.

This type of curve shows that the metal under examination is either a pure metal, a eutectic or a solid solution.

Here we have two new terms, "Eutectic" and "Solid Solution," which need explanation. It has long been known, almost common knowledge in fact, that when two or more substances are mixed together the mixture will have a considerably lower melting point than

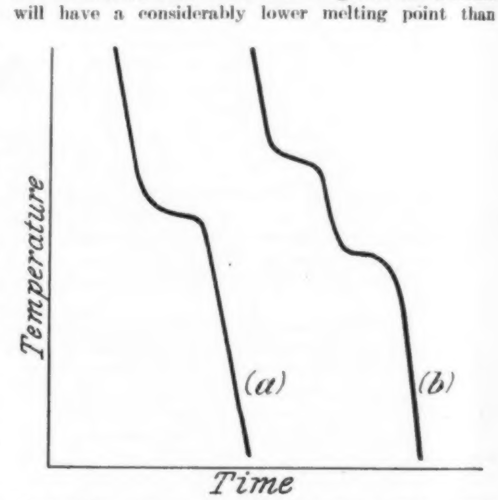

Chart of Cooling Curve. Note the Kinks, Which Correspond to Solidifying Points.

either of its constituents. And there is a certain mixture, of course, in the series which will have a lower melting point than any other mixture, this mixture is the eutectic.

In the alloys of gold and thallium, for instance, the alloy consisting of 77 per cent thallium and 23 per cent gold will melt at a temperature of 125 deg. Cent., whereas the melting point of gold is 1,100 deg. Cent. and that of thallium about 300 deg. Cent. This alloy

Fig. 4.—The Same Specimens as Fig. 3, After Annealing. Note the Clearly Defined Crystals, Magnified About 85 Diameters.

Fig. 5.—Tin-Zinc Alloy, as Cast. Shows the Characteristic Round "Grain" of Unannealed Cast Metals. Magnified 85 Diameters.

Fig. 6.—Ingot Copper (Electrolytic Copper Recast). Crystals of Copper Enclosed in Eutectic of Copper and Cuperous Oxide. 180 Diameters.

is called the eutectic of gold and thallium. A eutectic alloy under the microscope is very characteristic, and requires a very high magnification to distinguish the constituents.

As its name implies, a solid solution is exactly similar to a liquid solution. When a substance is dissolved in a liquid the particles of the solid become so small and intermingle so completely with the liquid that the substance is indistinguishable, so, in a solid solution, two substances are intermingled so completely and homogeneously that it is impossible to distinguish the two substances under the microscope.

The physical characteristics of solid solutions and eutectics are vastly different. Eutectic alloys are very hard and brittle and are never used commercially as it is impossible to work them. Solid solutions, on the other hand, are most desirable in an alloy. Common high brass consisting of 70 per cent copper and 30 per cent zinc is a solid solution, as is bronze containing less than 8 per cent tin, coinage bronze, German silver, standard gold and magnalium. Some alloys contain two solid solutions and these are less ductile than those with one solid solution, but they may be worked when hot. Among them are Muntz metal, Manganese bronze, Tobin bronze, and many other special bronzes and alloys.

As has already been mentioned, eutectics are very brittle, but this is not all of the evil properties of eutectics; an alloy that contains a considerable quantity of eutectic will only be as strong as the eutectic itself. The reason for this is, of course, the fact that since the eutectic has the lowest melting point it will solidify last, and as the crystals of the other strong constituents form in the solidifying mass of matter, the eutectic flows around them and thus forms an intercrystalline boundary of eutectic. See photomicrograph of copper (Fig. 5.)

To go back to the cooling curve, a curve such as (*b*) (See chart.) with two breaks, indicates that the alloy contains two different constituents, solidifying at different temperatures, which may be:

1. A pure metal and a solid solution of the one metal in the other, or
2. A pure metal and a eutectic, or
3. Two solid solutions, or
4. Any one of the foregoing together with a metallic compound.

These metallic compounds are true chemical compounds having definite formulas, such as Fe_3C (a constituent of steel, known as cementite), $CuSb_2$, Cu_4Sn, Cu_3P, CdSb, Ni_5P_2, CoSb, and many others.

These two types of cooling curves are the simplest and most frequently found, but in the alloys containing three or more metals, the curves are much more complex and are out of the scope of this article.

The next step in the examination of the alloy is the construction of the complete freezing point diagram for all the alloys in the series. This chart is quite easily constructed in the case of the binary alloys; the freezing points of the alloys being plotted along one axis and the percentage of one metal marked along the other axis. Above is shown the freezing point diagram of the lead-antimony alloys; the line *ABC* being the curve obtained by plotting the freezing points and the composition of the alloy. It will be seen that at the point *B* there is a sharp depression, this point is the eutectic and has a freezing point of 228 deg. Cent., and contains 13 per cent of antimony.

It will be noticed that the diagram is divided up into five divisions and any alloy in a division may have its physical properties foretold by consulting the diagram. For instance an alloy having the composition 20 per cent antimony and 80 per cent lead will solidify at about 250 deg. Cent., but while cooling from 250 degrees to 228 degrees, that is while it is in the space *BCD*, it will consist of solid grains of antimony surrounded by the still liquid eutectic. After passing the dotted line *ED*, that is, after it has passed 228 degrees, it will be totally solid and if it were to be examined under the microscope would be found to consist of crystals of antimony surrounded by eutectics.

These facts may be very simply stated by saying that any alloy in the space *BDFb* will consist of crystals of antimony surrounded by the lead-antimony eutectic; any alloy in the space *BCD* will consist of solid crystals of antimony surrounded by a liquid melt; any alloy in the space above the line *ABC* will consist of a liquid mass; any alloy in the space *ABE* will consist of solid crystals of lead surrounded by the lead-antimony eutectic, and finally any alloy in the space *EBbG* will be a solid mass consisting of crystals of lead surrounded by the eutectic.

A large number of alloys have been examined in this way and their freezing point diagrams constructed, and have been used to great advantage in commercial work. There has been constructed a very accurate diagram of the iron-carbon alloys which has been almost indispensable to the steel manufacturer, enabling him to control the physical properties of the metal in a very exact manner.

When a metal is strained or worked, as for instance in rolling or wire-drawing, it gets considerably harder, and in the working of alloys commercially it becomes necessary to heat them to a fairly high temperature, below their melting point, in order to make them soft again. This process is called annealing and may be defined as the release of strain in the metal. Copper alloys, for instance, harden very easily on being worked, and in the process of wire-drawing have to be annealed several times. The changes caused by annealing are well shown in photographs 1 and 4. Fig. 1 shows a piece of bronze which has been rolled and stamped; the constituents are hardly distinguishable, so distorted out of shape are they. Fig. 2 shows the same piece after it has been annealed at a temperature of 900 deg. Cent., for 15 minutes. It will be seen that the constituents have arranged themselves into large well-defined crystals. Figs. 3 and 4 show a similar condition in German silver.

The microscope, together with the principles of metallography, has rendered such invaluable aid to manufacturers of alloys in solving questions of hardness or "temper" as it is called, defects in annealing, etc., that it is hard to find a well equipped metal works where there is not a microscope, a camera and a metallographist.

A Direct Reading Accelerometer

An Instrument Which Reads Acceleration and Transition Curve Defects

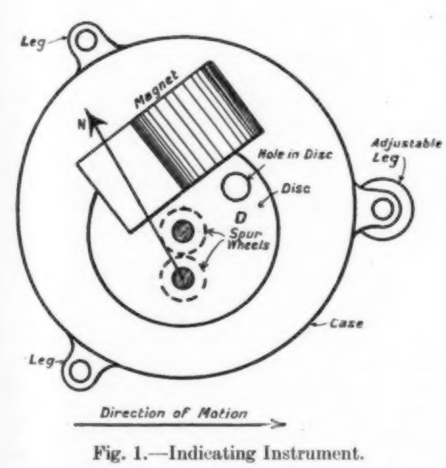

Fig. 1.—Indicating Instrument.

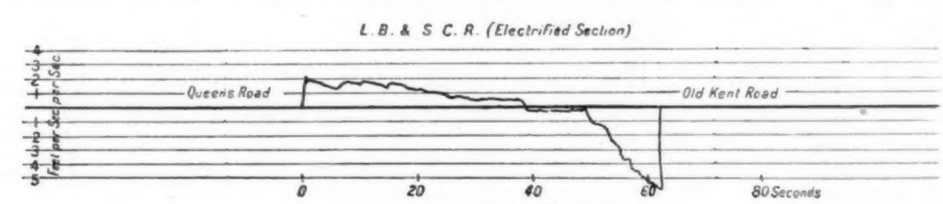

Fig. 3.—Acceleration Diagram.

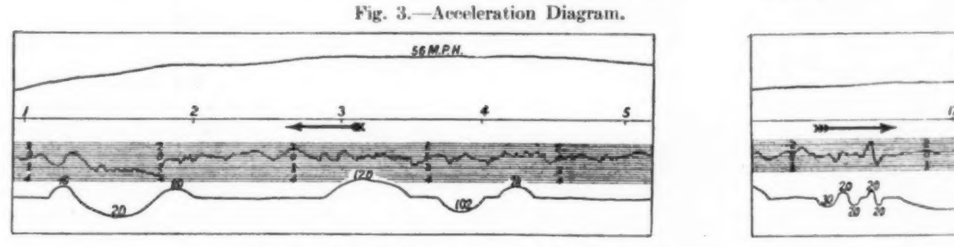

Fig. 4.—Equilibristat Curve. Main Line Express.

The accompanying drawing, Fig. 1 and photograph Fig. 2, show an electric recording and direct-reading accelerometer and equilibristat constructed by an English firm. The recording instrument for railway work gives charts of two kinds; one set of curves show the acceleration on starting, braking and coasting, so that the tractive effort can be measured at all speeds; another set of curves shows the nature of the lay-out of the line; the extent to which centrifugal forces when rounding each and any curve are balanced by the super-elevation of the outer rail; the safe speeds for negotiating the curves; and the effectiveness of the transition curves.

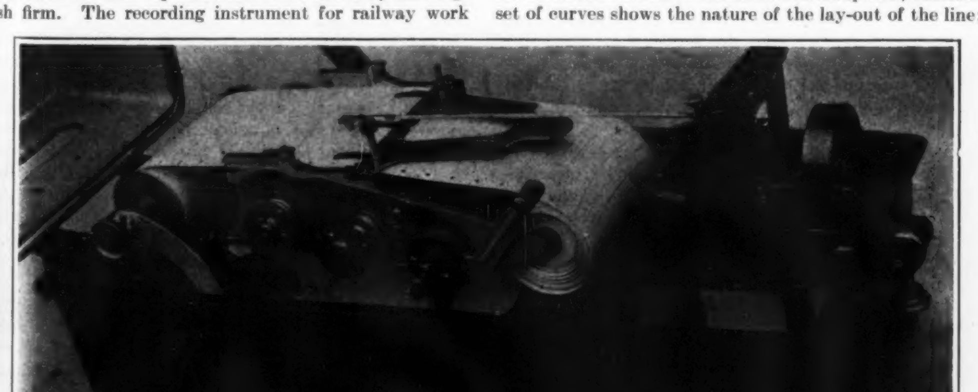

Fig. 2.—The Recording Instrument.

In the photograph the part below the paper rolls is the usual clockwork mechanism for winding the paper along at a uniform rate. The portion at the extreme right is the acceleration mechanism, which is arranged to read up to 8 feet or 12 feet per second. The indicating mechanism is noted in drawing Fig. 1. There is a copper disk or part of a disk, carried on a vertical axis, and controlled in its rotation by a coiled spring. Any acceleration in the direction of the arrow causes the heavier side of the disk to lag behind and so partially to wind up the spring. The degree to which the spring is wound up is a measure of the acceleration. Any tendency of the disk to oscillate can be checked by the magnet shown.

The device is set on the floor of the car and the screwed leg is adjusted till the needle reads zero for a level track. The clock is then wound up, and the pen proceeds to record the motion of the train. It is so placed, that when the pen moves parallel with the train, the instrument acts as an accelerometer and produces curves as indicated in Fig. 3, while when it is placed so that the pen moves across the carriage, it acts as an equilibristat.

The equilibristat curve is noted in Fig. 4, and in this case the same instrument is arranged to move across the train instead of along it. This curve is an effective indication of breaks of curvature due either to the absence, or to the ill design of transition curves which are easily seen and can then be corrected.

The Effect of Water Vapor in Promoting Combustion*

An Important Contribution to the Theory of Combustion and Oil Engine Practise

MOST engineers are familiar with the claim that the presence of water vapor in a boiler furnace promotes complete combustion. The weight of opinion undoubtedly is that such claims cannot bear the test of scientific analysis. The generally accepted scientific theory is that a steam jet discharged into a boiler furnace reduces the furnace temperature by reason of the high specific heat of the steam compared with that of the gases produced by combustion, and that while the superheated steam may give up a large part of the heat which it acquires in the furnace before it leaves the boiler and passes into the stack, yet a certain percentage of heat will be carried off with the steam and therefore the net effect is to reduce furnace efficiency. On the other hand, notwithstanding the weight of scientific opinion just cited, there is considerable evidence indicating that in the case of certain fuels at least the presence of steam in moderate quantity in the furnace does tend to promote complete combustion and reduce the amount of loss from unburned gases passing up the stack.

An interesting side light upon the problem above recited is furnished by the practical experience of the builders of various oil engines, which use as fuel instead of gasoline some form of kerosene or distillates of heavier gravity than the standard gasoline. The manufacturers of this type of engine have found by experience that a small amount of water vapor introduced in the cylinder along with the oil is of material benefit in making the engine run more smoothly and especially in producing complete combustion of the oil and preventing smoky exhaust and carbon deposits in the cylinder.

Now why should the water vapor have this effect? It is understood, of course, that the presence of water vapor will reduce the maximum temperature and pressure reached at the moment of explosion and may then, by virtue of its high specific heat, give up part of the heat it has absorbed to raise the expansion line of the gases on the working stroke.

The presence of water vapor in the charge also reduces the temperature attained during the compression stroke and thereby enables a higher compression to be reached without danger of premature explosion of the charge. This statement, however, does not account for the observed fact that the presence of water vapor promotes perfect combustion in the cylinder, lessens the smoke discharge and the carbon deposits.

The first attempt to give a scientific explanation of the action of water vapor in promoting complete combustion that we have anywhere seen, we find in a paper by James A. King of Charles City, Ia., which was read at the recent meeting of American Society of Agricultural Engineers.

Mr. King's paper was entitled "Low Gravity Fuels for Internal Combustion Tractors." As may be readily understood, one of the most important problems before agricultural machinery manufacturers is the production of engines for traction or other farm purposes, which will use ordinary kerosene instead of the expensive and dangerous gasoline used with most portable engines. Considerable success has been attained by several manufacturers in the production of engines of this type. As in the gasoline engine, a carburetor is used to furnish the explosive charge but the kerosene, instead of being vaporized, is introduced through an atomizer so that it enters the cylinder as a fine fog. As explained above, the use of a small percentage of water vapor with the kerosene had been found necessary to secure complete combustion. Mr. King offered in his paper above referred to the following explanation of the chemical action by which this result is produced:

"Into the problem of burning the heavier oils there enters a chemical peculiarity inherent in the more complex hydro-carbons. They are subject to what is known as 'cracking.' At a given temperature any one of them with a molecular formula above a certain degree of complexity will break down into a simpler compound.

"This temperature of cracking is below the temperature of ignition, and takes place without producing ignition. In this process of cracking a given molecule will break down into one or more molecules of the same series. Except in the naphthene or ethylene series this cracking results in the setting free of carbon.

"Since the paraffin series predominates in most of the petroleum fields of the United States, I shall confine this discussion to that series. The following equation will tend to illustrate what takes place when an oil 'cracks:' (1) $C_{15}H_{32} + \text{Heat} = 2\ C_7H_{16} + C$.

"As stated before, the temperature at which cracking takes place is lower than that of ignition. Consequently, this freed carbon immediately assumes a molecular state. This molecular carbon, unless prevented from doing so, is deposited as amorphous carbon and it is well known that amorphous carbon is decidedly inactive under normal conditions.

"The above illustrated action will explain why it is that the ordinary gasoline engines will not successfully burn these lower gravity fuels for any considerable time without a serious carbonization of the working parts of the cylinder and piston.

"In view of the facts set forth above and which are to follow, it is rather difficult to understand the credence given to the statement made after the close of the 1911 Winnipeg Motor Contest, that any engine will successfully burn kerosene and distillate simply by making a slight change in the carbureter by which the ingoing charge is heated so as to hasten the process of vaporization.

They will burn it, yes. But to burn it successfully they must do it with the greatest possibly economy and efficiency. To do it with economy an engine must get maximum combustion with minimum expense or interference with the working of the engine. To do it with efficiency the engine must burn this fuel in such a way as to realize a maximum percentage of the heat of combustion as useful work. In either case the engine must continue to do this throughout its normal life, not for a few hours or days. And it cannot do this without providing some means of uniting this freed carbon with oxygen under conditions which shall render the resulting liberated heat available as work.

"It was noted that when a charge of petroleum testing between 55 degrees and 38 degrees Baumé was ignited in the presence of a small quantity of water vapor, the combustion is much more rapid and complete than when the water is absent. Recognizing this fact, some manufacturers of kerosene-burning engines provide some system for spraying a small quantity of water into the cylinder coincident with the spraying of the fuel.

"The following chemical equations seem to explain the reactions which take place from the time the charge is drawn into the cylinder until combustion has ceased:

(1) $C_{15}H_{32} + \text{Heat} = 2\ C_7H_{16} + C$.
(2) $C_7H_{16} + 7\ O_2 = 7\ CO_2 + 16\ H$.
(3) $2\ H_2O + \text{Heat} = 4\ H + 2\ O$.
(4) $C + O_2 = CO_2$.
(5) $4\ H + O_2 = 2\ H_2O$.

"As stated above, reaction (1) takes place before ignition and is the process known as cracking. When the electric spark has ignited the charge a reaction such as (2) takes place. The heat generated by this is sufficient to run the temperature inside the cylinder of an engine working on normal load up to about 3,000 deg. Fahr. This temperature is sufficient to dissociate water and so the hydrogen of (2) does not unite with oxygen when released by the carbon in favor of oxygen, but remains free. At the same time reaction (3) takes place because of the high temperature generated by (2).

"Now free carbon and normal oxygen of the atmosphere unite only at very high temperatures, higher than those produced inside the cylinder of a working engine. But nascent oxygen is much more active, uniting at lower temperatures. So reaction (4) is coincident with (3). The nascent oxygen liberated by the dissociation of water in (3) unites immediately with the free carbon. Reaction (4) would liberate heat in compensation for that absorbed in (3), so that the pressure here would be maintained.

"Owing to the law of temperatures of gases under compression, as the piston moves outward the temperature of the gases within the cylinder decreases because of this expansion. At some point in the outward stroke the temperature falls below that of the dissociation of water. It is then, and not until then, that reaction (5) takes place. In this reaction the oxygen is that of the air and the hydrogen is that set free in reactions (2) and (3).

"The above paragraphs and equations will tend to explain how the presence of the water vapor gives complete combustion when burning these heavier, more complex oils. This simple expedient of spraying the water thus gives a high fuel economy. At the same time it also gives a high efficiency. By preventing the carbonizing of the cylinders, pistons and valves it keeps the engine running freely without the fouling effect of carbonization. This is quite important. Carbonization wears and ruins the working parts rapidly. It also collects in cones and other protruding shapes which are apt to become incandescent and so cause pre-ignition, with its attendant difficulties, losses and other evils.

"It increases the efficiency of the engine and also of the fuel by its effect on interior temperatures. These more complex fuels always run an engine hotter than do the simpler fuels when pulling the same load. This difference in temperature seems to exist especially at the compression end of the cylinder. If an engine's cooling system is designed to let the engine work at the highest temperature consistent with efficiency when working on gasoline, it will, when burning the heavier fuels, soon become so hot that the piston will bind and even stick in the compression end of the cylinder if no water spray is used. But the use of water overcomes this difficulty. The dissociation of the water, as shown in reaction (2), absorbs a great amount of heat and so reduces the total temperature of the cylinder chamber. Of course, this heat is again given up in reaction (5). But when (5) takes place the temperature has dropped below that point where it interferes with the proper working of the engine. So that the action of the water is not to decrease the total amount of heat units liberated during the entire process of combustion, but to so distribute it throughout the entire volume of the cylinder that the cooling system can properly control it. In fact, the presence of the water increases the total amount of heat units liberated, because it makes possible reaction (4)."

Mr. King in his paper above quoted distinctly stated that he offered the above as a working theory merely, and he did not claim to have made any tests or laboratory investigations to prove or disprove its correctness.

In response to a letter requesting further information as to the basis on which Mr. King has developed this theory, he writes as follows:

"The subject of utilizing low Baumé test fuels in internal-combustion engines of the Otto type seems to have but recently attracted seriously the attention of a very extensive public.

"For the past three years the writer has been operating experimental farms for the Hart-Parr Company, on which our kerosene-burning engines instead of horses have been used as the general motive power in doing all kinds of field work. The fuel generally burned in these engines has been 38 degrees Baumé test petroleum fuel, known as engine or Southwestern distillate, being secured from oils from the Kansas and Oklahoma fields. This fuel has been used regularly in our power house tests for several years.

"In our work with these engines we start them with gasoline. They are run from one to five minutes on this fuel until the cylinders become warmed up. Then the gasoline is shut off and the kerosene or distillate tank connected with the carbureter by opening the valve in the fuel pipe. The engine is allowed to run on this low-gravity fuel without the use of water until the engine has begun to pound from overheating, which occurs in a very few minutes with this fuel. Then the regulating valve in the water cup of the carburetor is opened gradually until this pounding ceases and the engine is still running well and powerfully.

"Now come the observations which led me to make the assumption regarding the chemical action of the water and also regarding the inability of the free carbon to unite with the normal oxygen of the atmosphere. While the engine is working on the low-gravity fuel without the water spray, the exhaust gases are noticed to be a heavy black from the presence of free carbon. So long as the water spray is not used this heavy black exhaust will be seen. When the water-regulating valve has been opened the proper distance, this black exhaust disappears and the exhaust gases are as clean and colorless as when burning a good grade of gasoline. In fact, the operator knows he has his water-regulating valve opened the proper distance when he has succeeded in preventing this black exhaust without having drowned his fuel with too much water.

"I have frequently opened the starting relief valves or the priming cups on these engines when they were operating on these heavier fuels without water and also running with water. When operating without water the flame is of a red color and often fringed with black smoke. The red color of a hydrocarbon flame is known to be caused by the presence of incandescent particles of carbon. The blackness of the smoke or gas often seen fringing this flame would, of course, be due to the presence of non-incandescent particles of free carbon. When water was being used with these fuels, the flame shooting from these openings would be a blue color, sometimes verging to a light yellow. This color would denote the complete or almost complete absence of free carbon in any form.

"In regard to the deposit of carbon within the cylinders, I would cite the following observation: One of our tractors under my control was run for over 200 days at heavy field duty, developing close to its maximum power continuously. At the end of this time compression was weakening and an examination was made for carbon deposits. Only a slight amount was found deposited in the first two piston-ring grooves, and this engine was worked always on these heavier gravity fuels.

"These observed facts seem to me to prove the following things:

"(1) Burning these fuels without the use of water spray produces a considerable quantity of free carbon which does not unite with the normal oxygen of the atmosphere under temperature conditions as they exist. A part of this is deposited within the cylinder and the rest is discharged with the exhaust gases.

* Reproduced from *Engineering News*.

"(2) The use of the water spray results in the oxidation of this carbon under temperature conditions existing in the cylinder. This oxidation is so complete that no serious deposit within the cylinders was noted at the end of a year's constant use of an engine, and no free carbon is noted by the eye in the exhaust gases.

"At the present time I am not in a position to authoritatively state that oxidation is produced by a chemical action of the water spray after the manner of my assumption in question. It may be that the action is more similar to that which takes place in the formation of water gas. It may also be that the water produces its effect by means of a catalytic rather than a chemical action. So far as I am familiar with the present sum total of the knowledge regarding the thermo-chemistry of hydro-carbons, to offer either one of these actions as an explanation of the method of oxidizing this free carbon is but to offer an assumed rather than a demonstrated explanation."

It seems that the matter presented by Mr. King is worth the careful attention of engineers and investigators interested in the development of internal-combustion engines, as well as of those interested in the problem of complete combustion of fuel of all sorts. It may be said that the combustion of oil fuel is so different from the combustion of coal that even if it were proved that the presence of water in the engine cylinder does not promote combustion, the same thing would not necessarily be true of combustion in a boiler furnace.

On the other hand, it is well understood that the gases given off from a bituminous coal with a high percentage of volatile matter contain as complex hydro-carbons as those contained in petroleum. It is quite within the possibilities that the presence of water vapor may act upon these gases in very much the same way that it acts upon the vapor produced from petroleum or its distillates in an engine cylinder. It is well to recall that the only thing which can burn is a gas, with the exception of carbon itself. All hydro-carbons, whether solid or liquid, must be reduced to the gaseous state before combustion occurs.

The Recent Flood in the New Subway at Berlin

A Serious Accident in the Section Under Construction Admits the River to the Completed and Operating Section Also

The German metropolis has recently been the scene of a serious accident which occurred at the site of the building operations on the subway tunnel under the Spree River. By a fortunate chance not a single life was destroyed, but the losses incurred by damage to the structure and by interruption of traffic have been very heavy.

It is somewhat unsatisfactory to gather one's information from the current newspapers published at the time of the accident, as such literature, written for the day, hardly furnishes the best kind of a record of events. Not only are they apt to be rather diffuse and written to catch the attention and hold the reader interested in an event which in most cases he has himself witnessed, at least, in part, with his own eyes, but it lies in the nature of things that a review written some time after the accident can take better account of all the circumstances and give each its proper weight, than the record produced piecemeal, each installment written in ignorance of what the subsequent installments will contain. We have recently ourselves had occasion to observe how unsatisfactory this mode of presentation, though useful for temporary purposes, is in giving one a correct survey of the situation, as we read during the past week our daily paper to keep ourselves informed so far as we could of the details of the "Titanic" diasaster. News may be published one day which is contradicted the next, and in order to finally extract a consistent account of an occurrence from newspaper records it is necessary to do something which amounts almost to research.

While, therefore, in presenting to our readers an account of a recent flood in the Berlin subway, we shall make use to some extent of data furnished from the newspapers, our main source of information will be a very excellent article appearing in *Elektrische Kraftbetriebe und Bahnen*. The writer says in part:

"There are three established methods which can be followed in building a subway below the river. The oldest process, which is particularly well adapted for a very deeply located tunnel and which has enjoyed particular popularity in London, consists in the use of a shield. This process was employed at the time the tunnel under the Spree between Stralau and Treptow was built, and was also resorted to in the extended operations in building the Hudson River and East River tunnels in New York city. It labors under the disadvantage that the work has to be carried out under very considerable pressure. This not only renders the operations very tedious and slow, but also greatly increases the cost, and furthermore has a prejudicial influence upon the health of the workmen. The second process, which can be used only in the case of a tunnel laid flat along the bottom of the river, consists in, first, preparing a tunnel casing above ground, and then sinking this into the river, to be finally dressed with concrete. This was the process employed, for example, at Paris, for the Seine tunnel, and also at Chicago, and on a very large scale in the Detroit tunnel of the Michigan Central Railway.

"In order to avoid interference with the river traffic, a new process was tried for the construction of the Spree tunnel of the Berlin Elevated and Underground Railway at present under course of construction. The work was carried out in two sections, one half of the river being first cut off by a cofferdam, exposing a strip of river bed, on which the first half of the tunnel was completed, working from above in open working and in absolute dryness, even some of the ground water being pumped out. After the first half of the tunnel was completed, the dam in question was torn down and another dam on the other half of the river put up, and work on the second portion of the tunnel was begun. At the time of the accident, the first half of the tunnel was entirely completed and was closed off by a concrete wall which, as events turned out, unfortunately gave way and admitted water not only into the new workings but also into the existing complete section.

"At the point where the tunnel is being built the river narrows down so that the total length of track under water will be about 429 feet. In profile the tunnel is rectangular and is arranged with a double track; it measures in width 22.18 feet and in height 11.22 feet. The walls are protected by iron plates 0.32 inch thick and a layer of basalt ballast 1.32 feet thick. The pit was about 74 feet broad, and the two dams on either side were 14.85 feet thick.

"After the first half of the tunnel had been completed, the second half was attacked. The pit was almost completely dug at the end of February, so that the concrete work was begun." A very good idea of the progress of the work up to this point is obtained from the very excellent illustrations which accompany this article.

Fig. 1 on our double page illustration following this page, shows a bird's-eye view of the first half of the tunnel. The cofferdam is clearly visible, as is also the wooden sheet piling rammed in for limiting the space of the pit in which the reinforced concrete tunnel is to be erected. In the foreground are perforated tanks belonging to fish dealers and containing live fishes. This photograph was taken October 7, 1910.

Fig. 8 shows a view of the inside of the tunnel on the riverside end of the first half. The concrete of the walls is here shown completed. The reinforcement of the corners of the roof and bracing of the open pit are the points of special interest. The concrete wall in the foreground is only provisional, and was to be removed when the second half of the tunnel had been completed. The date of this photograph is January 1, 1911. At the time of the accident the dividing wall, closing off the completed section, unfortunately gave way.

Fig. 7 is a very clear view along the axis of the first half of the tunnel. At this stage the concrete of the roof had been completed. The piping, which can be seen extending along the pit, served to lower the level of the ground water, thus rendering it possible to carry on the entire construction of the tunnel in an absolutely dry pit. This photograph was taken April 15, 1911.

In Fig. 4 will be seen the front end of the first half of the tunnel; to the left appears the cofferdam, in the middle the temporarily closed end of the tunnel; to the right over the roof of the end of the first half of the completed tunnel, is seen the piling, to be subsequently used as the end of the cofferdam pit for the second half of the tunnel. This photograph was taken May 6, 1911.

By June 9, 1911, when the photograph shown in Fig. 2 was taken, the first part of the tunnel had been completely finished and covered with water, and operations were in progress to remove the cofferdam which had been erected for the first half of the tunnel. The rear end of the pit shows the front part of the cofferdam to be erected for building the second half of the tunnel.

A little later, July 6th, 1911, as shown in Fig. 5, the larger part of the tunnel had been removed. Soon after this, ships would be at liberty to pass on the Spree over this part of the tunnel, while on the opposite bank of the river the cofferdam would be erected in building the second half of the tunnel.

The very excellent view which forms the frontispiece of this issue shows an island at the center of the river, which indicates the point of junction of the two halves of the tunnel. In the background can be seen the open pit, round which the work is continued toward Alexanderplatz on dry ground.

A view of the completed cofferdam for the second half of the tunnel is shown in Fig. 3, which dates from November 25th, 1911. The corner at the right, as events turned out, was apparently underscoured, with the consequence that the end of the finished part of the tunnel was underwashed and gave way, causing the formation of cracks in the walls and the consequent flooding of the completed section of the tunnel. Service was entirely stopped by the flood over a section extending from the Spittelmarkt up to the Leipzigerplatz for a week or more.

The view in Fig. 6, which was taken on December 12th, 1911, shows the open pit leading to the second half of the tunnel on the river bank.

The view shown in Fig. 4 gives an idea of the second half of the tunnel as it appeared two weeks before the accident. Iron reinforcing rods are placed in the concrete bedplates for the concrete walls of the tunnel. The two pipe lines, with many outlets to the wooden troughs on the right and left, are connected with mammoth pumps, which serve for maintaining low ground water level. This photograph was prepared March 16th, 1912, and is taken from the river end, looking toward the Alexanderplatz.

On March 27th, 1912, at 4 o'clock in the morning, for some reason as yet undertermined, the Spree River poured through the cofferdam at the point marked on the

Diagram of the Berlin Elevated and Subway System, Showing the Point Where the Water Gained Access to the Tunnel.

Fig. 1.—Birds-eye View of the First Half of the Spree Tunnel, October 7, 1910.

Fig. 2.—Removing the Cofferdam Erected fo ... g the Firs

Fig. 4.—The Front End of the First Half of the Spree River Tunnel, May 6, 1911.

Fig 5.—The Larger Part of the Cofferdam for Building ... Part of t

Fig 7.—View Along the Axis of the First Half of the Tunnel, April 15, 1911.

Fig. 8.—View Inside the Riverside End of th ... of the S

THE RECENT FLOOD IN T ... W S

Erected for ... the First Part of the Tunnel June 9, 1911.

Fig. 3.—Cofferdam of the Second Half of the Spree River Tunnel Completed, November 25, 1911.

for Building ... Part of the Tunnel Has Been Removed July 6, 1911.

Fig.6.—View of the Pit of the Second Half of the Tunnel Two Weeks Before the Accident, March 16, 1912.

ide End of the ... of the Spree Tunnel, January 1, 1911.

Fig. 9.—Open Pit Leading to the Second Half of the Tunnel, December 12, 1911.

D IN T EW SUBWAY AT BERLIN

diagram at the bottom of page 279. The pit of the second half of the tunnel was thus placed under water. Unfortunately, the matter did not end there. In some manner the water gained access to the second part of the tunnel and also poured into this, at first in a moderate stream, but presently with full force, flooding the entire line up as far as Kaiserhof.

As has already been intimated, by some fortunate providence the workmen received warning just in time to escape to safety before the pit was completely under water. Attempts were first made to stem the flood by throwing concrete, sand and other materials into the tunnels at suitable points and bringing all available pumping power to bear. It turned out, however, that the hurriedly constructed dams were far from water tight, and only after a more solid construction had been raised near the station at Spittelmarkt and a large number of pumps set going, was it possible to pump out the flooded section, this work being completed by Sunday, March 21st. After this a few more days sufficed to establish normal conditions again, so that by the 2nd of April, service was resumed in this section.

Very excellent service in the salvage operations was done by the electric rotary pumps and the large mammoth pumps which poured forth enormous quantities of water. Thus, for instance, on the evening of March 28th, when as yet the pumping machinery was not in full force, there were six rotary pumps, each delivering 700 cubic feet per minute.

As was pointed out at the beginning, there has been considerable damage done to the material, but the heaviest losses probably will be those ascribable to the interruptions in the traffic.

The accident is still at present as unexplained as it was at the time of its occurrence. It must be regarded as a most fortunate circumstance that no life was loss.

A Hunt for a Great Meteor*

The Commercial Possibilities at Stake

By Prof. Elihu Thomson

When I was a young man I came into possession of a piece of meteoric iron which was called a Canyon Diablo meteorite. It was said to have come from Canyon Diablo in Arizona, and to contain diamonds in addition to the usual constituents of nickel and iron. When I got this piece of iron I tried it on glass, and at last I found one little corner where I could draw it across the glass so that it left a mark like a diamond. There was a little piece of diamond imbedded in it which could be seen through the microscope. The meteor evidently has a story to tell us, but it was as late as about five or six years ago that I heard much more about this particular fall of meteoric iron, and then I learned that there was a crater about two miles to the east of Canyon Diablo, called Coon Butte. This crater has given rise to considerable discussion as to its mode of actual formation. Some claim that it is a volcanic crater; some that it is the result of a steam explosion, however produced; and others again aver that it was caused by the impact of a great meteor from the sky. I did not know at first which theory to accept as correct, but I have recently come to the conclusion that it indeed was the result of impact of a large meteor.

Last spring in going West over the Atchison, Topeka and Sante Fe Railroad, the opportunity came for me to visit the place and at least make up my own mind as to what happened at this point. I am going to try to give my reasons for thinking that it is a true meteoric crater, and where we can see a great many such meteoric craters if we look for them. On our trip we passed through the central part of Arizona, stopping over night at Winslow, and going the next morning a few miles farther west to the place that was so famous. We soon saw off in the distance to the southwest of the railroad track a peculiar kind of elevation on the plain, which all around was quite flat, although there were mountains in the distance on both sides. We were now in sight of Coon Butte, eight or ten miles away perhaps, which looked something like a water reservoir, with slopping sides and nearly flat top; but the color of the slopes was entirely different from that of the plane around, a kind of greenish gray as compared with the red soil which covers a great part of the territory known as the "Painted Desert." The Painted Desert is itself very beautiful, covered with sage brush and with red sandstone outcrops here and there. The peculiar hill, different from anything in the landscape, was the thing we were going to see.

We reached a little station called Sunshine, and indeed the sun did shine all the time we were there. It shone upon our enterprise, too, for we found a team which was to take us to Coon Butte six miles to the southward, the "meteor crater." We drove over a level country to the foot of Coon Butte and then up the slope for about 150 feet of height. As we were approaching it we passed fantastic outcrops of red sandstone, sage brush and other desert plants, here and there, all interesting; but for a long time the crater did not seem to get much nearer. This was due to the very clear air, so prevalent in that section of the country, shortening distance. As we at last went up the slope, we noticed the peculiar soil, a white silica soil, nearly pure silica, in which rested and over which were strewn large and small rock fragments grayish in color and apparently limestone. As we neared the top of the slope, of 150 feet, we had our first view of the crater, an enormous hole in the ground. It was a very impressive sight, indeed, that great bowl-shaped opening before us. Its greatest depth from rim to rim is 4,200 feet, and the average diameter is about three-quarters of a mile. The depth of the hole from the rim down is approximately 570 feet. From almost vertical sides at the top, the walls sloped down to an almost flat bottom.

To go around the rim was a long walk over irregular surfaces, and we did not expect to do that. The contour of the rim was very irregular, with broken and uplifted strata and rocks, pieces of rocks some times as large as a house, tossed out in apparent helter-skelter fashion. There were pieces of many tons in weight thrown a distance of thousands of feet on the plain. The outer slopes went down gradually to the plain, and were covered with broken masses and scattered materials evidently thrown out from this crater. But what threw them out? All over that territory, even to distances of several miles, hundreds of pounds of meteoric iron have been gathered and sent to all the museums in the world. Last summer I understand there was picked up on the plain, about a mile and a half away, a piece that weighed about 1,700 pounds; and there have been gathered pieces weighing 400 and 500 pounds all around there. Innumerable pieces of iron and oxidized meteoric iron are found in the material of the sloping rim.

Down in the crater all over the bottom is the white silica sand, a kind of fine white sand, called the rock flour, which looks like flour. It extends down in the crater to a great depth, all pulverized and mixed with small bits of meteoric material. Some of the iron rusted and corroded into brown hematite, called here shale ball iron. It is a peculiar feature of some of this iron that it rusts so rapidly. Some pieces of solid iron will, in our air, oxidize so rapidly that they are converted into this shale ball iron in a few months. This rapid corrosion is believed to be due to chlorine present in the particular pieces.

But how do we know that this is a meteoric iron? Well, every specimen gives what is called Wiedmanstatten figures, that is, if it is etched, it shows after smoothing a peculiar crystallization indicative of meteoric origin. There is still in this piece of corroded iron which I found at the crater a metallic center that is still uncorroded, but which will probably corrode in time. Another piece which I have is a bar of rectangular section cut on a planer. There was great trouble in cutting it; for every time the tool ran against a bit of diamond, it lost its edge. The iron can be ground by carborundum and materials like that, but in any case it is still a tedious process.

Mr. D. M. Barringer, of Philadelphia, to whom I am indebted for slides, specimens, etc., and for the opportunity to make our visit to the crater conveniently, was the first to indicate the possibility of finding a large meteoric crater, with probably a large amount of meteoric iron buried at some depth. A considerable amount of money has been spent in exploration, and the bulk of this was furnished by Mr. Barringer. The original intention was to sink a shaft, and drift sidewise when the shaft had reached such a depth that the rock showed no further signs of disturbance. According to all advices the sinking of such a shaft would be easy, because it would go through dry ground. Contrary to expectations, however, when the shaft reached about 200 feet below the floor of the crater, passing through this depth of fine, white silica or rock flour into the worst possible quicksand, it became impracticable to sink the shaft any further. This plan of attack, which was, of course, for the purpose of finding the meteoric body, had to be abandoned. A resort was then had to bore-holes.

There were put down 28 bore holes, some to the depth of 1,100 feet. In these were found pulverized rock, meteoric material, while at the bottom of the deepest holes undisturbed rock layers were struck. These were red sandstone underlying the white rock above. The trouble with these borings was that they were based on the supposition that the meteor had fallen straight down. In reality such a fall would be rare or unusual. These bodies almost invariably come on a slanting course through the air, and in this case the mass which fell is probably nearer or under the walls somewhere, but in a part of the crater not yet explored. I have made some rough calculations of the number of bore holes which would be required to make sure of finding it if it lay in the crater itself, and assuming the meteoric mass to have been 500 feet in diameter. It would require about 600 bore holes, which, at a cost of $2,000 per bore hole, would mean $1,200,000 spent in exploration. As I have said a large sum has already been so spent.

Why should anybody try to find this great meteor? As a commercial matter, of course, for the iron, nickel, platinum and diamond that it contains. There seems to be a general agreement that this crater would have required a meteor of about 400 or 500 feet in diameter for its production. The amount of rock thrown out and now existing in the crater walls is perhaps two or three hundred millions of tons. A great body of the material originally displaced must, of course, have fallen back into the crater, so that the actual displaced material is probably much in excess of the figure mentioned. But if we assume that one ton of material in the meteor was capable of displacing, say, some thirty tons of rock when it struck, then the mass of the meteor should have been approximately at a low estimate, say, five millions of tons, mostly iron. Eight per cent, however, would be nickel; and in each ton, by analysis, the average amount of about 0.6 (six-tenths) of an ounce of platinum and iridium exists. This would give about three million ounces of platino-iridium say; which at a valuation, say, of $30 to $35 an ounce, would equal about $100,000,000. If we assume, and of course it is a mere assumption, that one one-hundredth of 1 per cent of diamond exists in the mass, then the 500,000,000 tons would contain about 500 tons of diamond. There was indeed enough prospect of great value, even in case these figures should be largely exaggerated; and it is no wonder, therefore, that explorations were undertaken for the purpose of locating this great body. Thus far, as I have indicated, they have been without success.

Electrical men will naturally ask why the hunt was not carried out with a magnetic compass needle, or some instrument of that sort. Prof. Magie of Princeton actually did this. He used a very, very delicate dip needle, but absolutely failed to get any indications. He was naturally much disappointed when the magnetic instrument did not give the expected results; but it will be understood by those who have studied magnetism, that the permeability of iron, under very low magnetic forces, such as would exist there, is so small that it could not be expected to give any decided indications. Prof. Magie also found that while each individual specimen would show magnetic effects on the compass, a considerable body of them massed together gave little or no effect, the polarities apparently neutralizing one another. He has also told me that, in testing a large specimen, he found as many as twenty north poles, but that he could not find a single south pole on it. I am led to think that if this great meteor is found, it will probably be by some method using the induction balance; and I have planned a scheme which may possibly be useful in detecting the presence of this metallic body, or cluster of them, which, I have the utmost confidence, is still buried deep down in that hole.

One significant fact is, as pointed out by Mr. Barringer, that the south wall of the crater is uplifted 100 feet. A part of the plane and the strata immediately below are lifted upward almost horizontally 100 feet. It seems to indicate that something went under this part of the wall and lifted up the low land. There is again the finely pulverized rock, silica made by crushing from solid rock which is nearly pure silica. Some of it is evidently half fused by steam and heat, and looks like fused silica. It would indicate that great pressure or force has pushed the rocks laterally. These great masses of rock have been thrown out over the plain. The rim of the crater is, in fact, an enormous mass of ejected material; and one cannot escape the inference that something hit the earth there and hit pretty hard.

Mr. D. M. Barringer has been strong in his faith that it was a meteor and nothing else that made this hole, and I agree with him in his conclusions, assuming that it took an oblique course.

Now, what really took place at this part of the earth? I think the correct opinion is that, not one large meteor, but a cluster of them made up the total mass of iron. Now, a hole three-quarters of a mile in diameter is a large hole. We must admit that a very large mass of meteoric iron must have fallen from the sky into that hole. It was steam and gas liberated, coupled with the shock of impact that made the crater. The next question naturally is: how long ago did it happen? It rains out in that country at times, and there are high winds which shift the sands. There is but little evidence of erosion. The rock

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masses are broken very sharp, and the walls are not worn down. The slopes, although consisting of fine silica flour to a large extent, are not washed down. Certain cedar trees on the slopes appear to indicate that it has been there several hundreds of years at least; and there are other indications which make it appear that perhaps 2,000 or 3,000 years ago may be the time this great meteor fell upon the earth. North of this crater there is a large Indian reservation where the Navojo Indians live. These Indians, it is said, have a tradition handed down from generation to generation, which says that three large bodies fell out of the sky, and one of them struck the earth at the south of the present railroad tracks, i. e., where the present meteor crater is; and that when that body fell a number of their tribe were killed. These Indians now apparently send to this crater when the have their ghost dances, and get the white silica to sprinkle around where they dance, indicating that they still retain some superstition in regard to this peculiar natural phenomenon.

What actions take place when meteors enter the air? In the first place, that they come from space at a very high rate of speed is generally known. They certainly come from out of space, but we do not know from exactly where. The speed may be as high as forty or fifty miles a second. If it be a stony meteor, it may be crushed into dust by the air pressure in front of it. Even if of iron, it may be torn into fragments as if an explosion had occurred in front. If, however, it is a rounded piece of iron like this lump, then it would take a tremendous pressure of the air to crush it; and I have no doubt whatever that most iron meteors of rounded form would escape fracture unless they were moving at the very highest speeds. At such speeds, the air pressure developed in front of them may blow them to pieces; but if they are moving, say one-third as fast, they may, and probably will, survive unless they succumb to another action which takes place with iron, namely, combustion. Ordinary air contains one-fifth of its volume of oxygen. When at a pressure equal to 1,500 pounds per square inch the oxygen is condensed 100 times, and there is virtually an atmosphere of oxygen in front of the iron 20 times as dense as if the air were all oxygen. The compression produces an enormous heat in the gas and sets fire to the iron; the iron burns rapidly, almost like tinder. Now, if it burns for any length of time it will burn completely away, and if the meteor is a large one and it comes into the air with sufficient velocity to smash it, then the small pieces will burn vigorously in the oxygen of the air and may be consumed completely before they reach the ground; but if they are slow moving, or if the velocity is not high enough to crush them, then, instead of burning up, some part of them will come to the earth. When we find a piece of meteoric iron, it is one of these survivors. The pieces of iron, although they have been burning vigorously in the air may at last reach the ground solid and comparatively cool.

It is commonly thought that the meteor in passing through the air must get quite hot, but when we study the action more closely we see that this is not the case. The iron body, rushing along in the dense oxygen, burns and forms an oxide coating which is blown off as rapidly as it is formed. This coating is a thin film of fused, black oxide of iron, but the violent rushing of the meteorite through the air prevents any of this material remaining on the surface of the meteorite for more than an instant of time. The result is that the hot skin is, so-to-speak, stripped off in too short a time to communicate its heat to the interior of the mass; and the only heated portion at any instant is very thin skin which constitutes the exterme outside surface of the body. This is a somewhat different idea from the one most people have, I think. I will try to illustrate it. Suppose I take a block of ice and I set that block of ice on a stand and apply hot blast of air to it. The ice would melt on the outside and the water would be blown off, but the ice would remain ice to the very end of the process. We might stop the process at any time and find a nucleus of ice remaining, which would be, of course, solid.

Take a solid combustible, such as a piece of coal or wood, and apply a hot blast of oxygen to consume it rapidly. The coal or wood remains at a low temperature inside until the whole is consumed, assuming that it does not crack or fracture by sudden heating. The inside will be comparatively cold, because there is not time enough for the transfer of heat to take place from the outside to the inside. In the case of a meteor, the flight only lasts a few seconds, and that is a very short time for the heat to be transferred from the outside of the iron mass to its interior. The oxygen acts only on the outside; while the inside remains intact to the last, with its peculiar crystalline structure shown on etching, the Wiedmanstatten figures, which are not consistent with a high temperature. When we consider all sides of the case, it appears probable that the meteor that made the large crater at Coon Butte was moving at not more than two or three miles per second when it struck.

The question arises, why are there not more of these craters on the surface of the earth? There can be no doubt that there were a great many on the surface of the earth in the early ages, but the rains and erosive processes have long ago wiped them out. But let us take a look at our moon. In what kind of surface do we find the moon to be? There are a large number of craters all over its surface. These craters have been explained to be those of volcanoes on the moon; but in 1873 Proctor said that he did not think they were volcanic craters, but that they were meteoric craters, while 15 years ago a scientist by the name of Gilbert reiterated and enforced this view. I have often examined the moon through a large telescope and thought that the lunar craters have the appearance as if something had struck there; but when I came to see this meteor crater in Arizona, I felt sure that here we had a lunar crater on earth. We find on the earth an example of just such craters as are on the moon. The proportions are the same. In the meteor crater slopes are 150 to 175 feet high, while the hollow is down below the level of the plain or general surface, and that is just what is found with the craters all over the moon.

Furthermore, if one looks at the lunar craters through a telescope, they show characteristics which are different from volcanic craters on the earth, no great rivers of lava no cinder cones. One will often find in the large craters of the moon, encircled by their sloping walls, a mountain in the middle of the crater, some of them even something like 4,000 or 5,000 feet high. These central mountains are not topped with craters; there are no crater cavities to be detected at their summits, as is the case with the vents which form in the interior of the earth's volcanic craters at times. On the moon, however, the smaller craters seen through the telescope do not as a rule have these hills or mountains in the center; they are flat bottomed as in the case of the Arizona crater. It is only when the lunar crater is large that it has the central mountains, although, as a matter of fact, some very large ones do not contain this feature. How large, in fact, are these craters on the moon? Some of them 150 miles or more in diameter, others 40 or 50 miles, and others of sizes ranging down to a quarter of a mile or so in diameter, or as small as the revolving power of the telescope can show them. Why are there so many of these craters on the moon and so few on the earth? I have only to tell you that the moon is a body which has no atmosphere, no vapor, no gas, no water. All around the moon is a vacuum; there is no washing by rains to eradicate the surface marks, no erosion to level hills; and consequently all records of impacts remain. For that reason all the great holes on the moon created by meteoric masses are never disturbed unless another meteor strikes in the same place and obliterates, more or less completely, the first record. We have heard of one that was broken up into eight or nine groups. They split up, some of them are destroyed; and whenever we get anywhere near them we grab them.

It is probable that in the early history of both earth and moon many millions of years ago, they both received meteoric masses with a vastly greater frequency than has been the case in later years. From the fact that the peculiar bodies known as comets, which move in nearly elliptical orbits around the sun, are known to undergo the process of breaking up and dissipation into meteoric streams, the separate meteors or pieces being gradually gathered up by the planets, it is a legitimate thought that this process which is now going on is only the last stage of the grander cleaning-up of space which went on when cometary bodies were far more numerous and many times larger than they are at present. Indeed it is quite consistent with our ideas that the meteor which descended at Coon Butte was the nucleus of a small comet or a portion of one. It is a reasonable idea, too, that the planets themselves have to a large extent been built up by the gathering in of masses from space, like comets, through a long period of years. This process is still going on and will continue to go on until the whole of the cometary masses now moving around the sun are disintegrated, deposited or gathered up. It may be said to be a case of survival of the fittest. The cometary masses have erratic highly elliptical orbits in most cases, while the planets have orbits more or less approximating the circular. Naturally, then, the bodies moving around the sun having the more stable orbits would seem to feed upon those having the less stable orbits, with the result that the planets are built up out of the material composing their more erratic neighbors. In fact it is quite conceivable that the nucleus of a planet itself was originally just such a cluster as a large comet; but that it happened to be one which moved around the sun in a fairly circular orbit, with the result that it has grown at the expense of its neighbors. That comets do break up and disintegrate is evident, not only from the stream of material driven out in the tail, but in the fact that some of them actually are seen to split up into two or more bodies, and one is reported as having broken up into eight or nine groups of particles.

I remember as a boy seeing the great meteor shower in November of 1867. This shower had been recurrent every 33 years and was due to reappear in 1900. The path of the body of the meteors which furnished the shower was found to be coincident with that of Tempel's comet which had undergone disintegration. The earth was then gradually gathering up the *débris* or disintegrated material of the comet. Some perturbation of the orbit must have occurred which prevented the reappearance in 1900 of the brilliant meteoric display. But whence do they come, all these pieces of matter or fragments which move in cometary orbits? They are evidently fragments. They represent something which has been broken up. If we examine a piece of meteoric iron we find that it has a solid crystalline structure; possesses characteristics which could not have been imparted to it by the mere condensation of gases or vapors in space. It bears all evidences of having been consolidated at least by pressure, and possibly by heating. It appears probable that it was at one time a part of a much larger body, which body was disrupted or crushed and scattered into fragments, and that the gathering up process, which has built up the planets out of these moving masses, began soon after some great catastrophe happened to a former system. What is the nature of such a catastrophe? Do they really happen? To answer these questions briefly is to point out the fact that occasionally there is a sudden outburst in the sky which we call a new star. We may also state the fact that there are in space hundreds and thousands of so-called spiral nebulæ in all stages of aggregation. Now, two systems like the solar system, or large bodies like the sun, whether hot as the sun is, or cooled off to a black body through the lapse of time, may, and unquestionably do, sometimes pass by each other at comparatively close range, such as a few millions of miles one from the other. The result of such passage is, from the enormous strains due to the variation of gravitation and centrifugal forces, to practically crush the bodies and cause them to emit diametrically opposite streams of fragments and more or less heated particles, which streams, revolving, give us the peculiar phenomenon of the spiral nebula. The effect is the direct result of the condition which exists, that gravity is partly neutralized when the large bodies approach on the line joining them, while the centrifugal forces are greatly increased by their swinging around each other. The pressure of gravity in other directions is maintained at its full value, resulting in the inevitable crushing and emission of material from the bodies in two directions, like enormously exaggerated tides formed upon them. As the bodies pass by each other, with the formation of the spiral nebula from each of them, the gathering up of the *débris* or the scattered material begins, with the possible evolution of a new system from it. This, in fact, from all that we can learn, seems to be the order of nature. The process is seemingly a natural one, and has gone on for an illimitable past, and will continue to an illimitable future.

The action just outlined, as producing a spiral nebula, it must be borne in mind, is not that of a collision. Collisions of large bodies in space undoubtedly do occur, but from the nature of things, they will be extremely rare as compared with the cases of bodies which pass by each other comparatively near together. I use the word "comparatively" in this case as meaning that such distances as 5,000,000, 10,000,000, or even 50,000,000 of miles may be small as compared with the distances which now separate the stars or systems. Thus, the meteor which came down at the meteor crater in Arizona, if we could unravel its whole story, would tell us of the grand actions occurring in space in times inconceivably remote from the present. It would tell us of the possible breaking up of a former planetary system, and the gradual gathering up of material to form a new system, our own. It would tell us of the real processes which have built up the universe as it is, and which in the lapse of time will continue re-forming and re-making the systems with which it is filled.

Do Aquatic Animals Possess a Sense of Smell?

IT is generally supposed that the perception of odors in aquatic animals does not call for special organs, as the act of smelling in every case is combined with that of tasting. Since, however, in many of these animals special organs are found in the same spot where terrestrial organisms have their olfactory organs, Mr. Dolfein, according to the *Revue Scientifique*, maintains that whenever an aquatic animal possesses two distinct sets of organs, these are differentiated as regards their functions, one serving for taste and the other for smelling. This author cites in particular certain crustations of the genus coenobita, inhabiting warm climates, which have become adapted to life on the land, and which often travel a long way from the shore in search of food. These animals can be very readily attracted by presenting to them pandanus fruit, which has a very pronounced odor.

Thus it is perfectly obvious that they possess a very well developed sense of smell. While the animal is in motion the internal antennae are swayed to and fro with a characteristic motion. The author concludes from this that they are exploring the chemical qualities of the medium through which they are traveling. As a matter of fact, among the marine animals of the same type, the same motion is observed, and it must therefore be supposed that here also the antennae are subject to certain chemical stimuli and are presumably of the nature of olfactory organs.

What Is Terra Firma?*

A Review of Current Research in Isostasy

By Bailey Willis

WHAT are the foundations of the earth? On what do mountains, continents, and ocean basins rest? When men build they look to it that the foundations are firm enough to support the weight of the structure, or the building crushes its foundation and falls. Are there any rocks firm enough to bear the weight of mountains or continents without crushing?

The crushing strength of rocks, as ascertained in a testing machine, varies from 8,000 to 20,000 pounds to the square inch, and their average density is such that the weight of a column 3 to 5 miles high would crush its base. But among mountains there are many that are more than 3 miles high and some that exceed 5 miles. Their pyramidal form aids that portion of the foundation which is beneath the high peaks, but it has, nevertheless, been observed in tunneling that the rocks are in a state of great strain, as was the case, for instance, with the granite penetrated by the Simplon Tunnel beneath the Alps.

In the case of a plateau the form is that of a block, and where the height exceeds 3 miles the base probably approaches a crushed condition. Tibet thus stands above the general level of the Asiatic Continent. Asia itself may be described as a plateau, having an uneven surface, but rising on the average 3 to 4 miles above the bottoms of the ocean basins. Considered, then, as a mass whose base is on a level with the depths of the oceans, Asia is so high that its weight must exceed the load which can be supported by rocks, as we know them. The same is true of other continents.

Thus it seems reasonable to think that the foundations or rocks beneath the continents may approach a crushed condition or may actually be crushed.

Our thought has passed from mountains to plateaus and to continents. The foundations of continents comprise one-fourth of the earth's outer crust. The three-fourths which underlie the ocean beds obviously are no exception to the conditions described. At depths of 3 miles or more the rocks beneath the ocean basins must also be loaded beyond the strength of rocks at the surface and must approach a crushed condition.

This crushed condition is not, however, that of rocks which fall apart when crushed, for the foundations of continents and ocean beds are part of the solid earth and are continuous all about the sphere. There is, therefore, no space into which any crushed mass may crumble. The strength of the rocks may be overcome, but they can not fall apart. This condition has been reproduced experimentally and it has been shown that marble and even the firmest granite may be forced to change form, yet be held to a coherent solid. The rock under these conditions may be compared to wax, if only we bear in mind that it remains all the time a very strong solid.

The zone of crushing without separating has been called the zone of flow or flowage, because the movement of any rock mass under such pressures is compared with that of a very stiff fluid. But the word flow conveys an idea of mobility, and is thus misleading. It is necessary constantly to insist that rocks in the zone of flowage are rigid solids.

Solution plays an important part in the flow of rocks. Not that any large mass is dissolved at any particular time, but by the solution of a minute grain or molecule, which then flows from the point at which it was dissolved to a point where it is redeposited. The condition which causes solution is a slight excess of pressure or of temperature or both; and deposition from solution follows where these slight excesses disappear. Rocks are composed of mineral particles which differ widely in solubility and under adequate differences of pressure the less soluble may be granulated microscopically, whereas those crystals which are soluble in any moisture or mineral solution that may be present are dissolved and then recrystallized on a point that is less hard pressed. The individual element of motion is microscopic or even molecular, but the sum total of movements may affect a mass of subcontinental dimensions during a geologic epoch; that is to say, during a million years or several million years, more or less.

Movements in the foundations of continents are exceedingly slow.

In the zone of crushing, any rock mass of limited horizontal dimensions may be regarded as the base of a column that reaches to the surface of the earth. Being crushed by the weight of the superincumbent mass, it seeks to spread sidewise; but it can not because each adjacent mass, which is the base of an equally heavy column, also seeks to spread in the same manner and to the same degree. If, at any depth in the zone of crushing, one mass be under a heavier load than that borne by another adjacent to it, then the base of the heavier column will tend to spread with greater horizontal force than that exerted by the lighter column; but in order to cause movement, the excess of thrust from the heavier must be greater than the strength of the rocks under the lighter load. The last conclusion follows because the material against which the excess of horizontal pressure is directed is held to the condition of a rigid solid by the very load that crushes it.

It may seem as though the approximate balance of lateral pressures in the foundations of mountains, continents, and ocean basins were sufficient to explain the apparent stability of terra firma. But it will not have escaped attentive thought that the pressure beneath the mass of the Tibetan Plateau is sufficient to cause rocks at its base to spread near sea level. Or that the continental plateaus stand so high that their weight approaches the crushing strength of ordinary rocks near the level of the oceanic plateaus beneath the waters. Any lateral pressures, which may exist at these levels, are not opposed by lateral stress from an adjacent mass and stability depends upon the firmness of the rocks. Since the Tibetan Plateau and others stand, and since continents are stable, at least during very long periods of time, it would seem that rocks under these great loads must be stronger than the same rocks in the testing machine. This is, no doubt, to a certain extent true, and there is some experimental evidence to show that the rigidity of rocks increases greatly under high pressures.

The resistance which any solid offers to a permanent change of form is known to physicists as the viscosity of the solid, and it may safely be said that the viscosity of a solid increases under pressures applied from all directions in some ratio for each particular substance that is as yet unknown, but which, no doubt, gives the rigidity of steel to rocks a few miles below the surface of the earth.

Here we must introduce the idea of time. There is evidence to indicate that the huge masses of continents are not firm enough to maintain their altitude permanently; that in the lapse of ages they do spread laterally with a glacier like motion; and that the spreading lowers the surface. When this happens to a continent that has already been reduced by erosion to a low plain, the conditions are peculiarly favorable for submergence of the land beneath the sea, as has repeatedly occurred in the history of continents.

There is, furthermore, abundant evidence to show that at other times the bases of continents have been compressed laterally, squeezed, as it were. This effect has long been attributed to a contraction of the earth in cooling, as was first suggested by Dana, but the advances of geologic knowledge have greatly strengthened an old objection—namely, that contraction by cooling is inadequate to account for the amount of compression which the continents have suffered. While we know that continents have been squeezed, it is not known that ocean beds have been similarly affected. The broad flat ocean bottoms have rather the form of surface of a mass which flattens and spreads under its own weight. The writer has suggested that the spreading masses below the oceans may squeeze the masses beneath the continents, and finds a cause therefor in the fact that a cubic mile of the former is heavier than one of the latter. This brings us to the idea of differences of density in the earth's crust.

As far back as 1830 an English physicist, Airy, entertained the idea that some parts of the earth's crust might be heavier, some lighter, and in 1855 he contributed the suggestion to a discussion by Pratt of the attraction exerted by the Himalaya Mountains. In course of surveys in India it had been found that the great mass of that mountain range exerts an attraction, which was, however, much less than it should be, according to calculation, if the mass beneath the Himalayas were of the same density as that beneath the peninsula of India. Hence Airy and Pratt suggested that the mountains must be lighter.[1]

When Pratt wrote in 1885 no one doubted but that the earth had cooled from a molten condition, become covered with a rigid crust, and finally assumed its present configuration with all the detail of ocean basins, continents, and mountains. Although Pratt and Airy did not wholly agree, they both explained the lightness of the mountains by reasoning based on the processes of cooling and floatation of the crust on the still fluid interior. Now that it is known that the earth has the rigidity of steel and can not possibly be liquid within, the basis of their reasoning has disappeared and their theories are no longer entertained; but the inference as to the lightness of the mountains has been confirmed not only in regard to the Himalayas, but fo many other mountain ranges. It has also been shown that continental masses are relatively light as compared with those beneath the oceans. And it follows that if we think of a column beneath the continent and one beneath the ocean extending down to a common level, the taller column of lighter material can be of the same weight as the shorter column of heavier material. The two columns might then balance each other or be in equilibrium.

It seemed probable to Dutton and Gilbert 20 years ago that this relation of equilibrium was characteristic of the masses that make up the outer earth. Dutton discussed the problem in the following terms:

If the earth were composed of homogeneous matter, its normal figure of equilibrium, without strain, would be a true spheroid of revolution; but if heterogeneous, if some parts were denser or lighter than others, its

[1] Pratt, J. H. A treatise on Attraction, Laplace's Functions, and the figure of the Earth. 4th ed., pp. 93–94, 1871.

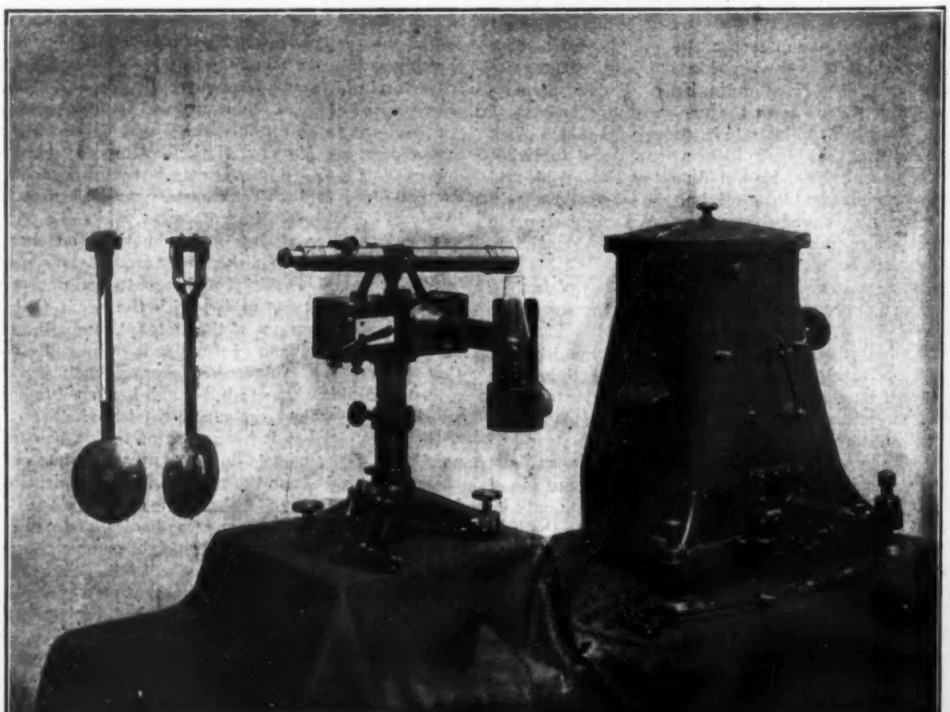

Fig. 1.—Pendulum Apparatus for Measuring Gravity.

* Reproduced by permission, from the Annual Report of the Smithsonian Institution.

normal figure would no longer be spheroidal. Where the lighter matter was accumulated there would be a tendency to bulge, and where the denser matter existed there would be a tendency to flatten or depress the surface. For this condition of equilibrium of figure, to which gravitation tends to reduce a planetary body, irrespective of whether it be homogeneous or not, I propose the name isostasy. . . . We may also use the corresponding adjective, isostatic. . . . The question which I propose is: "How nearly does the earth's figure approach to isostasy?"[1]

Gilbert,[2] in a measure, proposed an answer to Dutton's question. He had been engaged in original studies of the rigidity or strength of the earth's crust and had calculated that there was a limit to the mass which it could support without yielding. He expressed his view very conservatively, saying:

"It is believed that the following theorem or working hypothesis is worthy of consideration and of comparison with additional facts: Mountains, mountain ranges, and valleys of magnitude equivalent to mountains, exist generally in virtue of the rigidity of the earth's crust; continents, continental plateaus, and oceanic basins exist in virtue of isostatic equilibrium in a crust heterogeneous as to density."

Researches as to the distribution of lighter and denser masses in the outer earth have been greatly extended and highly refined since 1889. Dutton's general law is recognized as true. The larger elevations and hollows of the earth's surface are due to the balance of lighter and denser masses. Gilbert's suggestion that mountain-like masses and hollows are rigidly supported, commands consideration by conservative students. It is, however, apparently contradicted by the exhaustive calculations of the geodesist, Hayford, who concludes that the balance postulated by Dutton extends to masses which are much smaller than any which Dutton or Gilbert regarded as probably in equilibrium. In order to understand the present state of the problem we may briefly review the methods that have been employed in making observations.

Gravity is the force which causes bodies to fall toward the earth or a pendulum to swing. Its intensity may be measured by the velocity attained by a falling body at the end of a second, or by the number of swings that a pendulum of definite length will make in a definite time. The latter method of measurement is capable of very great accuracy and is used for all observations of the intensity of gravity on land. In order that the determinations may attain the desired precision and yet be carried out within a reasonable time, a highly specialized apparatus is used. The form employed by the Coast and Geodetic Survey is shown in Fig. 1.[3] A set of invariable pendulums is swung in an air-tight case in a partial vacuum, at a uniform temperature. An electrical flash apparatus makes the half-second beats of a chronometer visible and permits the observer to note when the beat coincides with a swing of the pendulum. The time of oscillation of the pendulum at the station where the intensity of gravity is to be ascertained is compared with the time of oscillation under identical conditions at a station at which the intensity is known. The desired value of gravity is then calculated.

The value thus obtained for the intensity of gravity at any particular place can be compared with the intensity at other places only by making all the conditions of attraction the same for both places. Let it be supposed that any two results which are to be compared have been obtained at stations that differ in latitude, in altitude above sea, and in topographic surroundings. Then account must be taken of all these conditions.

Latitude and altitude both affect the distance from the earth's center and gravity varies inversely as the square of that distance. Hence observations are reduced to sea level and are then compared with the normal value of gravity for the latitude of the observation according to a formula constructed by the German geodesist, Helmert.

Suppose, for instance, that an observation for gravity had been made in a balloon over the sea. It would be necessary to correct the result for the altitude of the balloon and compare with the normal value given by Helmert's formula for that latitude. This is what has been called the "free-air reduction." It is always made.

The calculation of the influence of position and topographic surroundings involves theoretical postulates which distinguish three different methods. One may be described as the method of high rigidity, since it rests upon the postulate of a rigid earth of uniform density. The other two both develop from the assumption of isostatic equilibrium, but they differ in that according to one the balance is supposed to be complete, but according to the other it is partial. An illustration may serve to make the distinctions clearer.

Let us transfer the place of observation from the balloon over the sea to the top of a lighthouse rising from sea level. The reduction for elevation, the "free-air reduction," must be made as before, but correction must also be applied for the mass of the lighthouse, which is an excess of material, added to and rigidly upheld by the rocks at sea level. It exerts an additional attraction, which must be deducted from the observed value in order to obtain the true value of gravity at sea level beneath the lighthouse. According to the postulate of high rigidity, all elevations on the earth's surface above sea level are excesses of mass which exert a similar extra attraction. A similar correction must, therefore, be applied to all observations which are calculated under that hypothesis. This was the reasoning of Bouguer, a French mathematician, who calculated the gravity observations made from 1736 to 1739 in Peru. The method is, therefore, known as Bouguer's method, and the mathematical formula as Bouguer's formula.

Had the lighthouse in this illustration not been an extra mass, added to the rock mass of its foundations, the correction for excess of mass should not have been made. But under the hypothesis of complete isostatic balance there is no excess of mass, since that hypothesis rests upon the assumption that all parts of the earth's crust which are, we will say, a mile square have the same mass, the heights of the columns above some common level within the earth being inversely proportioned to the density of the materials. The common level of the bases of the columns may be 100 miles below sea level, or it might be the center of the earth. All columns of the same cross section rising from it to sea level or to the heights of the Himalayas have the same mass by hypothesis. Hence there should be no correction for excess. The assumption of complete isostatic equilibrium is the basis of Hayford's work, which we shall see is the most recent and most exhaustive investigation of the subject. We shall, therefore, refer to the method of reduction based on it as Hayford's method.

Some thinkers on this subject hold that isostatic equilibrium can not be complete for every hill and valley of the surface, nor even for every mountain. They admit, however, the assumption that extensive masses, such as that of a whole mountain range or plateau, and defects of mass, such as that of the basin of the Black Sea, may be compensated or in equilibrium. The reasoning in this case proceeds on the basis that the mass of any large feature would be balanced at the altitude of a "mean plain," which is a hypothetical plain, that would be produced by leveling off the hills till the mass removed from them just filled the valleys. The total mass remains unchanged, since nothing has been added and nothing subtracted. The position of the mean plain depends upon the irregularities of the surface and is independent of the altitude of the station at which the observation for gravity is made. The mean plain may, therefore, lie above or below the station. If it lies above, there is a mass between the two which exerts an upward attraction and reduces the observed value of gravity by an amount which must be added to it; whereas if the mean plain lies below the station there is an excess of mass whose attraction is included in the original value observed and for which a deduction must be made. This method was first suggested by a French mathematician named Faye, and is known as Faye's method; but Putnam and Gilbert were the first to put it in practice and to elaborate the idea of the mean plain.

In the discussion of Hayford's method it will be seen that there is a correction for topography which is analogous to that for mean plain in Faye's method, but which has reference to a "theoretic plain that passes through the station."

The test which is applied to the results of calculations made under any one of these three different assumptions is that of agreement. All the values of gravity calculated by one and the same method should be the same. All the corrections which are applied are intended to eliminate from the original observation those items of attraction which may render the observed value greater or less than the normal value. Any difference which remains points to some factor that has been overlooked or to an erroneous assumption. That method of reduction which yields results in closest accord with each other is assumed to be nearest the truth.

We shall first contrast the assumption of high rigidity with that of partial isostatic balance combined with partial rigid support; and then compare the last with the assumption of completed isostatic balance, referring to the three methods, respectively, by the names of their authors, as Bouguer's, Faye's, and Hayford's.

In Bouguer's time no one doubted but that the earth's crust was very rigid. All masses above sea level were regarded as heaps upon the rigid crust and all depressions below sea level were taken to be defects of mass in the spheroid whose surface should correspond with that of the sea. Bouguer, therefore, corrected all observations for gravity by subtracting the attraction of the mass between the station and sea level. He obtained very small values. The intensity of gravity appeared to be so slight that Laplace, in the Mecanique Celeste, calculated the density of the material beneath the Andes as about equal to that of water, and he gravely suggested that the observed lightness might be due to great caverns within the volcanic zone. This suggestion is now recognized as quite untenable since rocks are not strong enough to maintain open spaces under the pressures that exist beneath the Andes.

A great many observations for gravity were made during the century and a half between 1739 and 1895, and all, so far as the writer knows, were reduced by Bouguer's method. They yielded a general result: The intensity of gravity on continents was found to be less than normal and was particularly low on high mountains; whereas the intensity was great on oceanic islands. Hence followed the conclusion that continents are light and suboceanic masses heavy.

[1] Dutton, C. E. On some of the Greater Problems of Physical Geology. Phil. Soc. Wash., Bull., vol. xi, pp. 51–64, 1889.

[2] Gilbert, G. R. The Strength of the Earth's Crust (abstract). Geol. Soc. Am., Bull., vol. i, pp. 22–25, 1889.

[3] Illustration kindly furnished by Mr. Geo. R. Putnam.

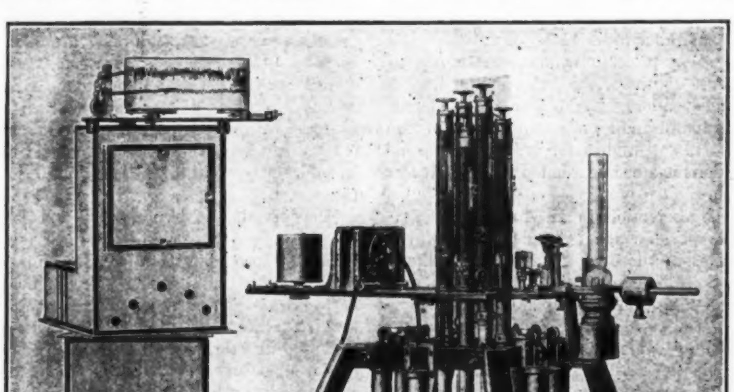

Fig. 2.—Hecker's Apparatus for Measuring Gravity at Sea.

But Bouguer's method yielded extreme results. Oceanic masses appeared to be very heavy and continents seemed excessively light, as Laplace's calculation of the density of the Andes should have shown. The anomalies resulting from Bouguer's formula led Faye, in 1880, to suggest that the correction for the attraction of the mass between the station and sea level should be omitted. He reasoned correctly that this mass is balanced and therefore is not equivalent to a weight which is carried by the rigidity of the crust. He distinguished between the masses which are "compensated," or, as we now say, balanced isostatically, and those which are in the nature of loads superimposed upon the crust, and he wrote:

"It must be clearly understood that even if the thickness of the continents above the sea has no place in the computation, this is not true, for example, of the mass of the great pyramid of Egypt, if one were to observe the oscillations of the pendulum at its summit. In that case, after having reduced the observation to the level of the sea, it would be necessary to subtract the effect of attraction of the pyramid above the level of the ground. In the same manner, if Bouguer had carried his pendulum to the summit of Pechincha, 1,500 meters above the level of Quito, it would be necessary to take account of the attraction of this mountain upon the pendulum of Bouguer."

It will be noted that Faye regarded the mountain Pechincha as a mass upheld by rigidity, but considered compensation or balance to be the condition of the larger mass below the plain of Quito. He had thus been led by studies in geodesy to views which Gilbert reached in 1889 by independent geological investigations. But Gilbert went further than Faye. He estimated the magnitude of the mass which the earth would support rigidly and placed it tentatively between 400 and 600 cubic miles.

Faye's method was first employed by Putnam in 1895 and independently by Gilbert, who collaborated with Putnam in the study of gravity observations made in the United States under the Coast and Geodetic Survey.

Putnam's results were also calculated according to Bouguer's method by Gilbert as well as by himself. The comparison with Faye's method was greatly in favor of the latter, as the values obtained by Faye's method were much more accordant, when reduced to sea level and the same latitude, than those obtained by Bouguer's from the same observations. The comparison was so much to the disadvantage of the older method that it may be said to be no longer worthy of consideration, and the very many results reached by it are of relatively slight value.

The accordance of results by Faye's method was so satisfactory that Putnam and Gilbert may be credited with having established beyond question the principle of isostasy as applied to the larger features of relief of the earth's surface. The small number (35) of stations considered by them and the limitations necessarily placed upon the computations for corrections nevertheless lessen the value of their estimates as to the load that the earth could bear rigidly. Putnam himself stated in his article that the residuals obtained by his computation were not precise.

In order to understand this qualification of their results it is necessary to consider the method of reducing the "mean plain." The position of that plain is such that the masses represented by hills, mountains, or plateaus above it are equal to the defects of mass represented by valleys or wider depressions below it. The position is calculated from topographic maps, whose accuracy thus enters into the computation, but a more important factor is the radius of the area about each station to which the estimate is extended. Gilbert took a radius of 30 miles and Putnam a radius of 75 miles, both investigators being limited by the labor of computation to a smaller area about each station than they would have chosen. Hayford has since shown that the attractions due to topographic features out to a distance exceeding 2,500 miles are not negligible, and for a work on the intensity of gravity in the United States, which is the latest published, he has extended the computations to the features of the entire globe. Thus the detailed residuals of gravity, the differences from the normal, obtained by Putnam and Gilbert, are suggestive rather than precise. Those investigators proved the isostatic balance of large features, but they did not demonstrate how small a feature may be isostatically balanced or how large a feature may be rigidly supported.

We have thus compared the hypothesis of high rigidity of the earth's crust with that of partial isostatic balance, entirely to the advantage of the latter. There remains the hypothesis of complete isostatic compensation, which postulates that all parts of the earth are nicely balanced. Hayford has employed this assumption as the basis of the most refined and extensive investigations as yet made on the subject.

The data which he has used are derived from the work of the United States Coast and Geodetic Survey and the computations have been executed by that organization. There are two elaborate investigations. One relates to deflections of the plumb line from the true vertical as determined at 507 stations of the precise triangulation which is the basis of the geodetic survey of the United States.[1] The other investigation relates to observations with the pendulum for gravity.[2]

Deflections of the plumb line are determined in precise triangulation by comparing the direction of the apparent vertical line with the true vertical which is fixed astronomically.

The deflection is due to lateral attraction, which may be exercised by mountain masses or by dense bodies within the earth's crust lying on one side of the station, or by both sources of attraction. The influence of topographic features, whose masses are more or less accurately determinable, can be calculated. There then remains a residual attraction which is presumably due to a dense body, but before accepting that conclusion it is necessary to eliminate any erroneous assumption that might have a similar effect.

Among the subsidiary investigations which Hayford made was one relating to the depth below sea level at which all the columns which extend downward from the earth's surface are balanced. At one extreme he calculated the values of gravity on the assumption that this depth, which is called the depth of compensation, is zero; that is, there exists immediately below every elevation the full compensating defect of density and below every depression the full compensating excess of density necessary to balance the inequalities of height. At the other extreme he calculated the values of gravity on the assumption that the depth of compensation is infinity; that is to say, the earth is so rigid that there is no compensation in the finite radius. He also made similar computations for intermediate depths of the level of compensation. That which gave the most accordant values of gravity and which is, therefore, regarded as most reliable was at first ascertained to be 114 kilometers, but was subsequently corrected to 120.9 kilometers. Helmert has arrived at the value of 123 kilometers by independent computations. There is, therefore, no doubt but that this value commands a certain confidence under the primary assumption of complete isostatic compensation. It may, however, be regarded as an average, from which there are in fact greater or less variations in different localities, and it also depends upon the postulate that the density of each individual column remains the same from the surface to the bottom at 123 kilometers. It is more probable that the density increases downward, and this would somewhat modify the value of 120.9 kilometers. Nevertheless this conception of a definite lower limit to the zone of compensation is of the highest value. At and below that depth all pressures due to gravity are by hypothesis equal.

In calculating the topographic correction before making the various computations for the depth of compensation, Hayford took account of all irregularities of the earth's surface to a distance of 2,564 miles from each station in all directions. The immense labor of these computations was brought within practicable limits by special methods devised to that end. As the stations ranged in position from the Atlantic to the Pacific coast, the depths of the Atlantic and Pacific basins were included among the features considered, as well as the highlands and mountain ranges of the continent. In the direct studies for gravity the scope of these computations has been extended to the features of the entire earth.

This topographic correction in Hayford's investigations occupies the place which the calculation of the "mean plain" takes in those of Putnam and Gilbert. But the plain of reference for the topographic correction under the assumption of complete isostatic compensation is the "theoretic plain" at the altitude of the station indefinitely extended in all directions. The mean plain and the theoretic plain will rarely if ever coincide, and the corrections, therefore, have different values. It is much to be desired that the "mean plain" correction and Faye's method, as used by Putnam and Gilbert, should be applied to all available data with the scope and detail employed by Hayford in order that we may have a comparison of the two methods on equally reliable results. The reason for this statement will appear presently in considering certain geological data that bear on the choice of method.

Hayford found that at each station there remained residual deflections of the plumb line after all the corrections had been made, and he regarded these residuals as evidence of departures from complete isostatic compensation. He says on this point:

"For the United States and adjacent areas it is safe to conclude from the evidence just summarized that the isostatic compensation is so nearly complete on an average that the deflections of the vertical are thereby reduced to less than one-tenth of the mean value which they would have if no isostatic compensation existed. One may properly characterize the isostatic compensation as departing on an average less than one-tenth from completeness or perfection. This statement should not be interpreted as meaning that there is everywhere a slight deficiency in compensation. It is probable that under some areas there is overcompensation as well as undercompensation in others."

Interpreting the preceding estimate in terms of altitude, Hayford places the average departure for the Continent of North America from that altitude which would correspond to perfect compensation at 250 feet. He further states that the maximum horizontal extent which a feature, such as a mountain, can have and escape compensation is between a square mile and a square degree.

It is evident that Hayford's studies on isostasy exceed all previous ones in exhaustive detail and in precision. Nevertheless there are geological considerations which suggest that the assumption of complete compensation is less satisfactory as a basis of reasoning than that of partial compensation and partial rigidity.

To present these considerations we must proceed from the fact that the features of continents are not permanent. They are the transient effects of two processes, uplift and erosion, which are opposed to each other, and which act intermittently. During certain epochs, of which the present is one, uplift has been dominant. Then continents have been large and mountain chains both numerous and high. At present continents are unusually large and mountains are unusually elevated. During other much longer periods erosion has exceeded uplift. Then continents have become low and featureless; great plains have prevailed; and in consequence of slight subsidence extensive lands have been submerged. These are facts of the geological record which admit of no doubt.

In this play of processes any particular part of the earth's surface may reach just that altitude at which it is in perfect isostatic balance, but it is not probable that the equilibrium can be long maintained. If the High Plateaus of Utah be in general in isostatic balance, then the Grand Canyon of the Colorado must be too light by the weight of the rock removed in carving it out of the plateau. It is, furthermore, certain that the Grand Canyon is but the beginning of that erosion which will eventually remove as much of the mass of the High Plateaus as lies above a plain, which will slope gently from no great altitude to sea level. If the region is now in isostatic balance, it will then be out of balance. Or, to consider another case: It is a commonly accepted fact among physiographers of the present day that the Appalachian region of the eastern United States was a low plain during the Cretaceous and early Tertiary periods. The plain is now warped up to 4,000 feet, more or less, above sea. If it is now in isostatic balance, it was out of balance during the long lapse of time of the periods named.

It is reasonable to link the movements which are expressed in the warped surfaces of continents with the stresses that are set up by disturbance of isostatic balance. It is probable that the stresses directly or indirectly cause the movements. But the effect is neither immediate nor constant. The disturbing process, erosion, is a very slow process. The plains which it produces endure during a geologic age. The earth is sufficiently rigid to be very slow in responding to the stress.

However, if the hypothetical relation of cause and effect exists between isostatic stress and warping, it is highly probable that equilibrium is most nearly perfect at the culmination of movements of elevation, such as the existing relief presumably represents. Valleys excavated by erosion represent disturbances of that equilibrium, which, therefore, can not be perfect in detail, or even very nearly so, as Hayford assumes and calculates, but the mass of any large area, such as the Great Plains of central North America, or the High Plateaus of Utah, is very probably nearly in equilibrium, considered as a mass and reduced to "mean plain."

Geological considerations thus afford reason to prefer the method of reduction employed by Putnam and Gilbert, the Faye reduction, rather than that used by Hayford.

The geological evidence which has been cited to show that isostatic equilibrium can not well exist in detail may be regarded as demonstrating a certain rigidity of the earth's crust, which is most severely taxed when erosion has planed away the compensating heights to the nearest possible approach to level plains. It is interesting to note that, *per contra*, the isostatic balance is probably most nearly complete in regions of most vigorous mountain growth, or for the continents as a whole is most perfect at a time like the present, when uplift is most general. If the disturbing process of erosion could be eliminated from continental activities the uplifts and subsidences would establish perfect equilibrium or a close approach to it. Now erosion has no effect over those portions of the ocean basins

[1] Hayford, J. F. The figure of the earth and isostasy from measurements in the United States. U. S. Coast and Geodetic Survey, Washington, 1909.

[2] Hayford, J. F. Supplementary investigation in 1909 of the figure of the earth and isostasy. Coast and Geodetic Survey, Washington, 1910.

which are beyond the reach of the sediments that surround the continents and which occupy nearly three-fourths of the surface of the globe. These areas are depressed because they are heavy, according to the hypothesis of isostasy, and should be depressed more or less according to the density of the underlying masses. The adjustment should be nearly or quite complete except where disturbed by vulcanism or by other special stresses. It is, therefore, of great interest to determine the law of distribution of density beneath the oceans in relation to the depth of the waters, apart from the interest which lies in the comparison of oceanic gravitation with that of continents.

As it is impossible to observe a pendulum on board ship, measurements of gravity in ocean areas were restricted to oceanic islands until recently, when they were made possible on the water by a method in which the pressure of the air as shown by a barometer is compared with the pressure of the air as determined by the boiling point of water.

In measuring the air pressure with a barometer the air is balanced by the column of mercury, which will be somewhat shorter at a place where the intensity of gravity is higher than at a point where the intensity is less. If the air pressure be measured by observing the boiling point of water, the result is independent of any influence of gravity upon the apparatus. By using both methods at a station the effect of gravity on the barometer at that station can be ascertained, and by comparing the effects obtained at various stations relative intensities are found.

This method, which was originally invented by the German physicist Mohn, was adapted to oceanic work by Dr. E. O. Hecker, who devised an elaborate apparatus for the purpose. It consists of five mercurial barometers which are hung in a metal plate swung on gimbals and which are so illuminated that the movements of the upper surface of the mercury are registered on a photographic film. The record is a wavy line, since the barometers are constantly agitated by the motion of the ship, but with the aid of a special apparatus which registers that motion the effect on the barometer and their actual reading can be ascertained. (Fig. 2.)

Hecker took numerous observations on voyages from Lisbon to Bahia, from Bremerhaven through the Mediterranean and Suez Canal to Sidney, from Sidney via New Zealand, Tutuila, and the Sandwich Islands to San Francisco, and thence back to Japan. Apart from certain anomalies in volcanic districts and in the Tonga Deep, which is a vigorous earthquake center, the results correspond with what the theory of isostasy requires. The intensity of gravity over the ocean basins is everywhere normal. That is to say, there is the same mass beneath each part of the ocean surface; each such mass or column is composed of two parts, water above and rock below. The shorter the rock part, or the deeper the water, the heavier or denser the rock part must be, or, putting the relation in terms of isostatic balance, we may say the denser the rock the deeper the hollow in the earth's surface.

The confirmation of the isostatic law for the oceanic basins is of great importance in supporting the probability of a similar balance for the continents against the ocean basins and within the continental masses as well.

The present state of investigation into the subject of isostasy may reasonably be summed up as follows:

It is demonstrated that the larger masses of the outer earth, above a zone 120 kilometers deep, strive toward isostatic equilibrium. The condition of perfect balance has been most nearly attained within the ocean basins; the general balance of the continental plateaus and of the broad features of relief is at present also nearly perfect. If so, it is probable that the culmination of this mountain-building epoch is approaching, or is past.

Erosion is a process which destroys those elevations of the continental surface which appear to be essential to equilibrium, and which are probably a result of the effort toward it. The balance at any time is disturbed to the extent that erosion exceeds uplift. The long periods when, according to geologic evidence, lands have been low and featureless, have been periods of failure of equilibrium, periods of stress, when the low continental masses resisted uplift by virtue of rigidity.

Isostasy and rigidity both are conditions of the earth's mass. Their relative effects in the changes of stress in the earth vary with the state of uplift or erosion, and it is an interesting coincidence that intelligent research should investigate the condition during an epoch when equilibrium is most nearly complete and rigidity least severely stressed. But we may not overlook the fact that this condition is but a transient one.

If we apply these considerations to the question with which this review began, What are the foundations of the earth? We may answer: The foundations are solid rock, which is self-crushed to a depth of 120 kilometers, more or less, which is rendered sufficiently rigid by pressure to maintain its form during prolonged geologic periods with but very slight change, in spite of stresses occasioned by erosion of continental reliefs, but which is capable of movements that from time to time result in the gradual elevation of continents and the more vigorous uplifts of mountains through which isostatic equilibrium is restored.

Our Immigration Laws from the Viewpoint of National Eugenics*

By Prof. Robert DeC. Ward of Harvard University

How far do our present immigration laws enable us to exclude those aliens who are physically, mentally, and morally undesirable for parenthood; those whose coming here will tend to produce an inferior rather than a superior American race; those who, in other words, are eugenically unfit for race culture? We, in the United States, have an opportunity which is unique in history for the practice of eugenic principles. Our country was founded and developed by picked men and women, and to-day, by selecting our immigrants through proper legislation, we have the power to pick out the best specimens of each race to be the parents of our future citizens.

The social responsibility which rests upon this country in this matter is overwhelming. We may decide upon what merits—physical, intellectual, or moral—the fathers and mothers of American children shall be selected; but we have left the choice almost altogether to the selfish interests, which do not care whether we want the immigrants they bring, or whether the immigrants will be the better for coming. Steamship agents and brokers all over Europe and eastern Asia are to-day deciding for us the character of the American race of the future.

It is no argument against practicing eugenic ideas, in the selection of our alien immigrants, to say that the New England country towns are full of hopelessly degenerate native Americans, who are inferior, mentally, morally, physically, to the sturdy peasants of Europe. The degeneracy of our country native stock is probably chiefly due to the drawing off of the stronger and more capable men and women to the cities; to prolonged inbreeding, and to the continued reproduction of feeble-mindedness, which is rife in many of our country districts. It will not help to reduce the number of our native degenerates if we admit alien degenerates. National eugenics, for us, means the prevention of the breeding of the unfit native, as well as the prevention of the immigration and of the breeding after admission of the unfit alien.

CAREFUL ABOUT IMPORTING CATTLE, CARELESS ABOUT IMPORTING MAN.

Should we not exercise at least the same care in admitting human beings that we are now exercising in relation to animals, to insect pests, or to disease germs? Yet it is actually true that we are to-day taking more pains to to see that a Hereford bull or a Southdown ewe, imported for the improvement of our cattle, are sound and free from disease than we take in the admission of an alien man or women who will be the father and mother of American children. We do not hesitate to prohibit the importation of cattle from a foreign country where a serious cattle disease is prevalent. It is only in very extreme cases, indeed, that we have ever taken such a step in connection with the importation of aliens. Yet there are certain parts of Europe from which no aliens should be allowed to enter this country, for reasons which are eugenically of the first importance.

Our present laws aim to exclude some twenty-one classes of mentally, physically, morally, and economically undesirable aliens. On paper the list of the excluded classes is long and formidable, and seems more than sufficient to accomplish our eugenic purposes; but the fact is that careful and unprejudiced students of immigration agree that these laws do not keep out the unfit so as to preserve the *status quo*, to say nothing of promoting eugenic improvement. We already have an army of probably not less than 150,000 feeble-minded in the United States, of whom only about 10 per cent are in institutions, the rest being free to propagate their kind. And of those in institutions, the large proportion are kept there only temporarily, being at liberty for much of the time during their reproduction period.

The same is true of thousands of criminals, whom we shut up for varying periods of time, but allow, in the intervals when they are out of prison, to populate the world with children, much of whose inheritance is criminal. We are to-day legalizing the begetting of criminal children by failing to give permanent custodial care to habitual criminals.

Further, there are over 150,000 insane in the institutions of the United States alone, and of these many have already left offspring to perpetuate their insanity. In spite of this appalling situation—appalling from the standpoint of mere sentiment and of mere philanthropy—doubly appalling from the standpoint of eugenics, we have been admitting alien insane and alien imbeciles, and alien epileptics and alien criminals, partly because of a lax administration of the law under former administrations, partly because the law is incapable, under existing conditions, of effective enforcement. The disproportionate increase of alien insane, of alien imbeciles, of alien criminals, and many other facts which may be ascertained by any person who is interested in this question, shows that, as just stated, our immigration laws do not now enable us to preserve the *status quo*.

Sir Francis Galton has clearly shown that "each married degenerate produces on the average one child who is as degenerate as himself or herself, and others in whom the taint is latent, but liable to appear in a succeeding generation."

Further, it is well known that imbeciles have larger families than normal persons, and that they also have a large number of illegitimate children. Parenthood on the part of all these classes of persons, native or alien, is a crime against the future. To admit to this country the feeble-minded, the insane, the epileptic, the habitual criminal, those afflicted with hereditary diseases, is no less a crime against the future.

The ideal selection of our immigrants would be possible only if we could have a fairly complete history, running back a few generations, showing the hereditary tendencies of each alien. This is impracticable, so far as the immediate future is concerned. But there are some things we can do. We can insist that each alien, on landing here, should undergo a very thorough mental and physical examination at the hands of our Public Health and Marine Hospital Service surgeons. These examinations would involve the stripping to the skin of each alien; the usual physical examination for physical defects; mental tests; tests for syphilis, and similar precautions. Is this too much to demand when the welfare of the human race is at stake?

I have seen thousands of aliens landed, and I have marveled at the skill with which our surgeons are now able, by the most superficial examination as the aliens file by, at the rate of several a minute, to detect some of the physical and even some of the mental defects which put these aliens into one or another of the classes which may be excluded. But such a superficial examination is all wrong.

It is nothing short of a crime to admit people, as often happens in a rush season, at the rate of 3,000 to 4,000, or 5,000 in one day at Ellis Island. On April 11th, 1910, 7,931 immigrants were inspected by the medical officers. Think of that! And these medical officers were supposed to detect any mental and physical defect which might exclude!

I believe that we ought to limit the number of aliens who shall be landed in one day to a certain number which could reasonably well be carefully inspected. We ought largely to increase the number of the surgeons detailed for that most important work of inspecting arriving aliens. We ought to enlarge the accommodations at some of our immigrant stations, in order that this work might be properly carried out.

Again, we can go a long way toward the accomplishment of our object by increasing the fines which the steamship companies now pay when they bring over an alien who is found on our own examination here, to be an idiot, imbecile, epileptic, or suffering from a loathsome or dangerous contagious disease which could have been detected at the port of departure. The fine is now only \$100. The steamship companies pay little attention to the provision. They run their chances of having such aliens detected on landing, and in some cases they insure themselves against possible loss by obliging the alien to deposit \$100 when he buys his ticket. Now if we increased this fine to \$500—and that is none too large—the steamship companies would themselves, without expense to us, make a much more thorough examination abroad before sailing.

Further, for the more effective detection of aliens who are physically, mentally, and morally undesirable, and

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who are already enumerated in our list of classes excluded by existing law, we should put immigrant inspectors and our own surgeons on board of all immigrant-carrying vessels. These officials, mingling with the immigrants on the voyage over, should see that they are properly treated and cared for; that they are not overcrowded and that they receive adequate medical attention.

But, of far greater importance than that, these officials would be able to detect a great many cases of physical and of mental defect which we could not possibly detect in our necessarily hurried examination when these people land, and in this way we should be able to exclude and to send back far larger numbers of undesirable aliens than is at present possible, however strictly we may try to enforce the law.

In addition to these steps which we should take, and take instantly, to accomplish the more effective exclusion of the insane, the imbecile, the idiot, the tuberculous, and those afflicted with loathsome or dangerous contagious diseases, we ought to amend our laws so that it will be possible to exclude more aliens of such low vitality and poor physique that they are eugenically undesirable for parenthood. The law of 1907 excludes persons "who are found to be and are certified by the examining surgeon as being mentally or physically defective, such mental or physical defect being of a nature which may affect the ability of such alien to earn a living." This clause has been found to be rather ineffective, partly because it has been taken to be an economic test and not a physical one; partly because of other provisions in the same act which largely nullify this section by making it possible to admit on bonds aliens who fall into the group here named.

Now aliens of such low vitality, poor physique, or suffering from such mental or physical defect that their ability to earn a living is thereby interfered with are, in the majority of cases, highly undesirable persons. They are not only themselves weaklings and unlikely to resist disease, but they are likely to have defective and degenerate children. Bonds will not prevent them from breeding.

We constantly speak of the need of more "hands" to do our labor. We forget that we are importing, not "hands" alone, but bodies, also. The vast majority of incoming alien immigrants are potential fathers and mothers, and the character of the race that is to be born depends upon the kind of alien bodies which we are allowing to have landed on our shores day by day. It is a tremendous responsilbility which rests upon us.

Conservation of our national resources: how much we hear about that. Conservation of American forests is important. So is conservation of American coal, and oil, and natural gas, and water supply, and fisheries. But the conservation and improvement of the American race is vastly more important than all other conservation. The real wealth of a nation is the quality of its people. Of what value are endless acres of forests, millions of tons of coal, and billions of gallons of water if the race is not virile, and sane, and sound?

Fearfully misguided has been most of our so-called philanthropy. We have housed and clothed and fed the defective, the degenerate, the delinquent, to such an extent that we have encouraged them to reproduce their kind in ever-growing numbers. We have spent increasing sums for asylums, almshouses, prisons, and hospitals, in which we have temporarily confined the insane, the pauper, the habitual criminal, the imbecile, leaving them free, during most of their lives, to propagate their kind. It is a fact, disguise it as we will, that we have taxed ourselves to support institutions which have resulted in increasing and not decreasing the number of the unfit.

We have before us an immediate duty of tremendous importance in caring for our own unfit; in seeing to it, by adequate legislation, that the insane, the habitual criminal, the feeble-minded, and similar classes are permanently segregated, so that they cannot reproduce their kind to be a further burden upon the nation, and in enacting laws which shall prevent the marriage of those whose offspring will be unfit.

But, in addition to our own very heavy burden of those who are defective or degenerate, we are adding every year, by immigration, many hundreds if not thousands of aliens whose presence here will inevitably result, because of their own defects or those of their offspring, in lowering the physical and mental and moral standards of the American race.

Biologists admit that they have much to learn about heredity. But of some things we are already sure. Enough is known to make it absolutely essential, if the quality of the American race is to be preserved, that there should be a far more careful selection of our incoming alien immigrants, on eugenic grounds, than we have ever attempted.

The need is imperative for applying eugenic principles in much of our legislation. But the greatest, the most logical, the most effective step that we can take is to begin with a proper eugenic selection of the incoming alien millions. If we, in our generation, take these steps, we shall earn the gratitude of millions of those who will come after us, for we shall have begun the real conservation of the American race.

Military Appropriations for Aeronautics in France

Nothing is more significant of the importance attached to the subject of aeronautics abroad than the appropriations included therefor in the French budget, the report of which we take from the journal *Le Temps*.

The Chamber and the Senate have provided in the budget of 1912 a total sum of 11,906,010 francs; 11,206,000 francs for material, and 700,010 for men. This sum is divided into 3 parts, as follows:

Chapter 16, engineering wages	700,010 francs
" 34, engineering establishments	3,600,000 francs
" 103, engineering material for war	7,606,000 francs

In round numbers this is 12,000,000 francs, which may be allotted thus:

Spherical balloons and *personnel*	800,000 francs	($160,000)
Dirigibles (programme of March 25th, 1910)	5,000,000 francs	($1,000,000)
Aviation (approximate figures)	6,200,000 francs	($1,240,000)

M. Millies-Lacroix, who reported the budget, took pains to remark that he proposed to adopt these figures in order not to retard the general vote of the budget, but that it must be perfectly understood that the expenditures necessitated in 1912 by aviation and dirigibles would reach at least 25,000,000 francs ($5,000,000).

He stated that he estimated that future expenses in this connection would reach an annual sum even larger. Hence the next budget, for 1913, would be established upon an estimate in the neighborhood of 30,000,000 francs.

Here is the intended programme:

"It is my ambition," said M. Milleraud, as he declared to the Chief Council of War on the 25th of last January, "to frame a plan in such manner that the appropriations so generously voted may be utilized in the best possible manner, so that if, as is possible in the course of execution, innovations appear indispensable, and certain changes of advantage, still the larger portion of the money will have been expended usefully."

As far as dirigibles are concerned, to begin with, the programme agreed upon February 25th, 1910, will be resumed and pursued. A uniform type, the cruiser, will be adopted. Twenty will be built at the rate of five per year; fifteen different types are already constructed or are in course of construction in addition to the cruisers, scouts and a vedette. In the future such of these types will be replaced as progress may render necessary.

Before announcing the aviation programme the Minister of War indicated that the unit of aviation in time of war would be the "escadrille" or squadron of "avions" (the name given a military aeroplane).

An "escadrille" is composed of 8 machines divided into 4 pairs: one of "monoplaces" (one man), one of "biplaces" (two men), and one of "multiplaces" (several men). Besides these there will be a reserve pair consisting of one "monoplace" and one "biplace."

Each squadron is provided with rolling stock for transporting the machines themselves as well as what may be termed their supplies, i. e., fuel, lubricating oil, tools and extra parts.

This rolling stock, in the shape of a number of automobiles, also assures the captain's keeping in touch with headquarters.

For each pair of areoplanes of a squadron there are two tractors and a truck, or a total of 9 automobiles for each squadron.

According to M. Millerand there were about March 1st 13 squadrons capable of being put in commission (8 in the field and 5 in reserve), representing a total of 104 "avions," in place of 208, which ought to be available.

As regards centers of aviation, about 30 are to be established, including those already opened. There will be, in fact, a dozen principal centers, around which will be grouped twenty annexes.

These centers will serve as "school-depots," i. e., they will serve at the same time as schools of instruction and as points of centralization for the squadrons. Some centers will be either central schools reserved for instruction or central depots reserved for concentration.

There will be, besides these, aviation fields reserved for corps where there is no aviation center, in order to permit the local officers to become familiar with the use of the "avions." There will likewise be installations in the camps of instruction and at local shooting schools.

Each center of aviation will have at its head a chief charged both with technical instruction and with executive administration. He will be assisted by officers (comptables), foremen of workshops, and a staff of civil and military workmen.

The *personnel* of a squadron will be composed of 7 pilots, one of whom is captain of the unit; of an officer of administration, of 4 sub-officers, one of whom is an adjutant mechanician, and of 44 corporals and sappers.

This is the "specialized" staff. The non-specialized *personnel* comprises 2 sub-officers and 14 soldiers.

There will be a total of 234 pilot officers and sub-officers, 42 sub-officer mechanicians, 110 sub-officers and 1,600 corporals or special sappers; 42 auxiliary physicians, 42 sub-officers and 550 non-specialized persons.

Concerning dirigibles M. Reymond states that the figures are not in accord with those published on February second. Our statistics indicated for Germany, with the reserves, the number of 25 dirigibles. According to the honorable senator, there are but 10 German military dirigibles in commission.

For French dirigibles our statistics indicate 21, which we have thus classified: 5 doubtful, 4 in commission, 3 on trial and 9 available. We are not far off the figure of "10 units capable of rendering service" estimated by M. Reymond.

As for the new fund which the Chamber will vote, they may be apportioned thus, according to the statement made to the Senate.

Dirigibles.		
Material	3,000,000 francs	($600,000)
Aviation.		
Material (11,000,000 francs). *Personnel* (1,000,000 francs)	12,000,000 "	($2,400,000)
Credits which will be proposed	15,000,000 "	($3,000,000)
Credits already voted for 1912	12,000,000 "	($2,400,000)
	27,000,000 "	($5,400,000)

The above sum will be divided as follows:

Spherical balloons and *personnel*	1,000,000 francs	($200,000)
Dirigible balloons	8,000,000 "	($1,600,000)
Aviation	18,000,000 "	($3,600,000)
	27,000,000 "	($5,400,000)

The Emission of Particles from Heated Metals

Some very interesting experiments are reported in a recent issue of *La Nature* with regard to a discharge of particles from the surface of heated metals, which manifests itself by the formation of an image upon a piece of another metal placed in the neighborhood of the article heated. The outlines of the image thus formed naturally decreases in sharpness as the distance between the heated object and the receiving surface increases, but in general contour the image corresponds unmistakably to the shape of the metal which is emitting the particles. The time required to form such images is comparatively short, about half a minute's exposure furnishing very excellent copies. The projected particles carry an electric charge. A peculiar observation in connection with this phenomenon is that the power of emitting these particles decreases and after a certain time disappears, the metal exhibiting a kind of "fatigue." Another very remarkable circumstance is that when the experiment is carried out in an atmosphere of hydrogen, instead of obtaining the usual image, corresponding in extent to the surface of the heated metal, a kind of negative image is produced the surface of the metal piece being represented by a blank, and its edges showing as broken bands. As regards the explanation of this phenomenon, the following has been suggested: It is known that all metals absorb gases at their surface, and that under certain conditions these gases are liberated by heat. It is, therefore, supposed that when the temperature of the metal is raised the gas is ejected from the surface, and in this way an explosive emission of metal particles is produced. If this explanation is correct the phenomenon can hardly be regarded as related to radioactivity.

The Production of Moving Picture Films.—The first cinematograph pictures were displayed in 1895 by the brothers Lumière. At the present time the daily consumption of cinematograph films is figured at 985,000 feet, giving an annual consumption of 300,000,000 feet. If we figure the purchasing price of one foot of the film at about 3.8 cents, we find that the annual amount expended for these films is $11,500,000. Films on the market ready for use cost about 7.6 cents per foot. The original films are made principally in the United States, France, and Germany.—*Prometheus.*

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